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Water Quality of Urban Storm Water Runoff in the Borough of East York

Research Report No. 66

Research Program for the Abatement of Municipal Pollution under Provisions of the Canada-Ontario Agreement on Great Lakes Water Quality

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Water quality of urban storm water runoff in the borough of East York / Mills, W. Gordon.

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WATER QUALITY OF URBAN STORM WATER RUNOFF IN THE BOROUGH OF EAST YORK

by

W. Gordon Mills
Director of Engineering
Borough of East York

RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION WITHIN THE
PROVISIONS OF THE CANADA-ONTARIO
AGREEMENT ON GREAT LAKES WATER QUALITY

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ABSTRACT

Two study areas were established in the Borough of East York, with one area, Broadview, being abandoned after a short time due to instrumentation problems. The other area, Barrington, was monitored for a period of almost three years. Water quality results are given for eighteen events at Barrington and three at Broadview. Parameters recorded throughout the study included suspended solids, BOD, lead, phenolic compounds, chlorides, COD, total and dissolved phosphorus, ammonia, Kjeldahl nitrogen, nitrite, nitrate and conductivity. Parameters recorded occasionally included pH, TOC, sodium, potassium, iron, hardness, alkalinity, dissolved and total solids, sulphates, heavy metals, petroleum hydrocarbons and herbicides.

Barrington is an old residential area, with combined sewers constructed in the 1920s, and the separate storm sewer system built in the late 1960s. All tests were run on separated storm water from the new storm sewer system. The drainage area was 22.4 hectares, of which 17.4 hectares contributed runoff to the sewer system, since the roof drainage was connected to the older combined sewer system.

Results are provided in tabular form, and include the peak concentrations of all parameters in all events monitored, peak mass loadings for all events (mass loading being the rate at which the parameter is being carried by the runoff), the mass of material carried by runoff in each event, and the flow-weighted mean concentration for each event. Results are also provided in graphical form, including 291 graphs (all of which are available on request). Each graph shows the rainfall, concentration and mass loading for each parameter in each event. Only a sample number of graphs are included in the report.

The author recommends upgrading of municipal housecleaning programs, treatment at pollution control plants for low flows in separated storm sewers and for the first hour's runoff from a rainstorm, and revisions to legislation governing runoff quality.

RÉSUMÉ

Nous avons établi deux régions d'étude dans la municipalité d'East York, soit Broadview et Barrington. Des problèmes d'instrumentation ont causé l'abandon prématuré de l'étude menée à Barrington pendant presque trois ans. Nous donnons des résultats compilés au cours de 18 orages à Barrington et de trois à Broadview. Les paramètres enregistrés tout au long de l'étude comprenaient les matières en suspension, la DBO, le plomb, les composés phénoliques, les chlorures, la DCO, le phosphore total et dissous, l'ammoniaque, l'azote de Kjeldahl, les nitrites, les nitrates et la conductivité. Les paramètres enregistrés à l'occasion comprenaient le pH, la COT, le sodium, le potassium, le fer, la dureté, l'alcalinité, les matières totales et dissoutes, les sulfates, les métaux lourds, les hydrocarbures et les herbicides.

Barrington est un vieux quartier résidentiel dont le système d'égouts combinés date des années 20 et le système d'égouts pluviaux indépendants de la fin des années 60. Toutes les épreuves ont porté sur les eaux pluviales de ce dernier. Seuls 17,4 ha des 22,4 ha du bassin de drainage déversaient leurs eaux dans le système pluvial puisque l'eau des toîts s'écoulait dans l'ancien système combiné.

Les résultats sont présentés sous forme de tableaux et comprennent, pour tous les orages surveillés, les concentrations maximales de tous les paramètres, le débit massique maximal, c'est-à-dire, le débit des matières (au sens le plus général), la masse des matières transportées par le ruissellement et la concentration moyenne, pondérée en fonction du débit, au cours de chaque événement. Deux cent quatre vingt onze graphiques (disponibles sur demande) rendent également compte des résultat. Chacun d'eux contient des données sur l'intensité de la précipitation, la concentration et le débit massique de chaque paramètre et de chaque événement. Le rapport ne comprend qu'un certain nombre de ces graphiques.

L'auteur recommande une amélioration des programmes municipaux de nettoyage, l'épuration des écoulements faibles provenant des égouts pluviaux indépendants et de la première heure de ruissellement suivant un orage, ainsi que la révision de la législation portant sur la qualité des eaux de ruissellement.

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CONVERSION FACTORS

This study has been reported entirely using metric units. Following are some useful conversion factors:

1 cubic foot per second	=	28.3 litres per second
1 pound per hour	=	0.454 kilograms per hour
1 acre	=	0.405 hectares

1 INTRODUCTION

Combined sewer overflows have been in existence ever since the first treatment plant was constructed at the end of a combined sewer system and designed to handle only the dry weather flow. Overflows were not recognized as a significant problem when the sewer systems were constructed and received little attention at the time. When attention was focused on them, they were found to be significant contributors to water pollution due to the high content of untreated sanitary sewage which they contained. With the recognition of the problem caused by overflows came the proposals for their elimination.

In the Metro Toronto area, the method adopted was the construction of separated storm sewer systems. In the early 1960's storm sewer separation reports were prepared for the City of Toronto, Township of East York, and the Township of York, the three municipalities in which most of the combined sewers in the Metro area had been built. Action soon followed, with the first storm sewers constructed in East York in 1964 and in the City of Toronto in 1966. From 1965 on, the author was intimately involved with the construction of the storm sewer system in East York.

The approaches taken by East York and by the City of Toronto were similar in that a new storm sewer was constructed on a street and all the street catch basins were connected to it. The City differed from East York in that the City's system was designed to accommodate only road drainage, with no allowance for house services. East York's system was designed to accommodate roof drainage as well as road drainage because of the number of areas reporting basement flooding due to surcharged sewers and the number of new high-rise apartment buildings being constructed. In anticipation of the construction of this sewer system a bylaw was passed in 1961 requiring all buildings in the (then) Township to be constructed with separated drain systems, regardless of the sewer system in the area. In combined sewer areas the drains were to be connected at the street line with a single combined drain on the road allowance. When the storm sewer is constructed on the street, the

storm drain is disconnected from the sanitary drain at the street line and connected to the new storm sewer, and a completely separated system is produced.

Several problems soon made themselves evident after construction of the new sewer system had begun. The cost, as predicted in the various reports, was high and getting higher. Second thoughts were expressed in some quarters that perhaps some other method of eliminating combined sewer overflows should have been adopted which would have been cheaper and just as effective. With the majority of the main outfalls already installed and several million dollars spent on trunk and local storm sewers, however, the municipalities were committed to this method, and could not seriously entertain thoughts of major changes in basic approaches.

The second concern expressed was that the old combined sewers on the streets, now converted to sanitary sewers with the removal of the storm water from them, were carrying only a fraction of the amount of water which they had formerly carried, with consequent reduction in flow velocities. The resulting loss of carrying capacity caused more solids to settle out and remain in the pipe, resulting in increased sewer cleaning costs and possible blocking of the sewer in extreme cases. Only time and experience will provide the evidence to determine if this is a legitimate cause for concern, but preliminary indications are that there is no great problem.

The third concern was simply the question: now that storm runoff was being diverted from the combined system and conducted directly to the rivers, was the water quality of this runoff sufficiently better than the quality of combined sewer overflow water to justify the fantastic cost involved? In order to gain some insight into the answer to this question, the author has chosen to study the water quality of urban drainage in the Borough of East York.

2 LITERATURE REVIEW

Compared with studies of urban runoff as a factor in combined sewer overflows, very little work has been done on the water quality aspects of separated urban storm water runoff. Following is a discussion and review of several studies in this field or in related areas.

In 1954 a study of surface runoff from a 248-hectare (611 acre) estate with separate sewers at Oxney, England [1], showed BOD levels up to 100 mg/l and suspended solids contents up to 2045 mg/l. BOD levels tended to increase with the length of the antecedent dry-weather period up to eight to ten days; after that little further change developed. Computations were made to compare discharges to the river from the separate system with a hypothetical combined system wherein all flow would receive treatment. On the basis of assumed treatment plant effluent levels of 20 mg/l for BOD and 30 mg/l for suspended solids, it was concluded that the separate system reduced the BOD loading on the stream but increased the suspended solids loading by six or seven times. First flushes were not much more polluting than subsequent flows, except after long antecedent dry periods.

A translation of a report on the results of a sampling study of storm water runoff in Moscow, U.S.S.R. [1], in 1936 indicated BOD levels of 186 to 285 mg/l and suspended solids of 1000 to 3500 mg/l. Runoff samples from Leningrad's cobblestone paved streets in 1948-50 contained BOD levels of 36 mg/l and suspended solids of 14 541 mg/l.

Storm water samples from Seattle street gutters [1], in a study made by Sylvester in 1959 and 1960, contained constituent values as follows: turbidities, up to 1290 units; colour, to 350 units; BOD levels with aerated Green Lake water as the diluent, about 10 mg/l; coliforms, to 16 100 MPN per 100 ml. Nutrient values were: organic nitrogen, up to 9.0 mg/l; nitrate nitrogen, to 2.80 mg/l; and phosphorus, to 784 µg/l soluble and to 1400 µg/l total, as P. The highest constituent concentrations usually were found when antecedent rainfall had been low.

Summer rainwater drainage samples, mainly from streets and parks in Stockholm, Sweden [1], from 1945 to 1948, indicated median values for coliforms at 4000/100 ml; COD, 188 mg/l; total solids, 300 mg/l; fixed residue, 210 mg/l; and BOD, 17 mg/l. The levels for individual samples ranged as high as 200 000/100 ml for coliforms; 3100 mg/l COD; 3000 mg/l total solids; 2420 mg/l fixed residue; and 80 mg/l BOD.

Storm water samples from residential, park, school, and sports ground type areas in Pretoria, South Africa [1], revealed coliform counts of 240 000/100 ml; total organic nitrogen, 5.4 mg/l; COD, 29 mg/l; dissolved solids, 228 mg/l; and BOD, 30 mg/l. From a business and flat area, the concentrations were: coliforms 230 000/100 ml; total organic nitrogen, 0.5 mg/l; COD, 28 mg/l; dissolved solids, 154 mg/l; and BOD, 34 mg/l.

These figures point out the limited amount of work which has been done, the wide variety of components of the runoff which have been measured and the extreme variations in the results. These five studies have little in common with the situation in a North American urban environment, except the Seattle study, which was confined to runoff in the gutter and did not include effluent from a storm sewer.

The first major study of North American urban runoff which appears to have been done began in the Detroit area in 1949 and culminated in the mid 1960's with an elaborate study of combined sewer overflows in Detroit and a separated storm system in Ann Arbour. Beginning in 1949, Palmer [2] sampled storm water runoff from land surfaces at street catch basins in downtown Detroit. He found BOD levels in the order of 96 to 234 mg/l; total solids, 310 to 914 mg/l; and coliform ranges of 25 000 to 930 000/100 ml. He also reported similar samplings during a number of Detroit storms in 1960.

Following Palmer's work in downtown Detroit a study was undertaken of combined sewer overflows in Detroit and a separate system in Ann Arbour, Michigan. Results of the Ann Arbour section of this study are quite applicable to this work and are presented below.

Work on the Ann Arbour sewer took place during the period April to September, 1964, and a total of ten storms were sampled [3].

Total coliforms were reported as ranging from 26 500 to 17 500 000 per 100 ml, median value. Median fecal coliforms varied from 7500 to 1 115 000 per 100 ml. Median fecal streptococci values varied from 13 800 to 730 000. Chemical analyses results for several components were also reported, with the statistical mean as follows:

Ammonia Nitrogen as N	-	0.48	mg/l,
Organic Nitrogen as N	-	0.36	mg/l,
Suspended Solids	-	1280	mg/l,
Total Phosphates as PO_4	-	2.9	mg/l.

The ratio of fecal coliforms to fecal streptococci was reported to be about 0.6, indicating pollution derived from animals other than man.

A further study of the same two systems was made in 1965, but this time no bacteriological samples were taken [4]. Only the chemical and physical properties were studied. Eleven parameters were measured, and the Ann Arbour annual mean and maximum values observed were as follows:

	Maximum Value Observed	Annual Mean
Phenols, mg/l	70	16
BOD, mg/l	62	28
NH_3 - N, mg/l	2.0	1.0
Organic N, mg/l	4.0	1.0
Suspended solids (SS), mg/l	11900	2080
Volatile suspended solids (VSS), mg/l	570	2.8
Sett. Solids, mg/l	11100	1590
Vol. Sett. Solids, mg/l	475	140
Soluble PO_4, mg/l	3.4	0.8
Total PO_4, mg/l	16.4	5.0
NO_3- N, mg/l	3.6	1.5

Studies in Cincinnati have been reported on at least three different occasions. The first work was done in 1962 and 1963 [5]. The study area differed quite drastically from Ann Arbour where the drainage area was 1544 hectares (3800 acres). In Cincinnati the area amounted to only 11 hectares (27 acres) of which some was parkland.

Results of the 1962 - 63 work were as follows:

		Maximum	Mean
Turbidity		1000	170
Colour		380	81
pH		8.7	7.5
Alkalinity, mg/l		210	59
Hardness as $CaCO_3$	Ca	200	63
	Mg	46	15
	Total	246	78
Cl		35	12
SS		1200	210
VSS		290	53
COD		610	99
BOD		84	19
Nitrogen (as N)	NO_2	0.2	0.05
	NO_3	1.5	0.4
	NH_3	1.9	0.6
	Org.	4.8	1.7
PO_4 (total soluble as PO_4)		4.3	0.8

Bacterial results were reported in the following form:

	Counts Exceeded in Designated percent of Samples (colonies per 100 ml)		
	90%	50%	10%
Coliforms	2900	58 000	460 000
Fecal coliforms	500	10 900	76 000
Fecal streptococci	4900	20 500	110 000

Seasonal variations of these parameters were also given. Except for BOD, which peaked in the spring of 1963, there were no significant changes throughout the year.

The second article on the Cincinnati study area investigated methods of treating urban runoff by plain settling and treatment with

chlorine [6]. Evans et al reported that less than one hour of plain settling was not helpful in reducing COD, BOD, nitrogen, phosphates, solids, or the densities of the three bacterial indicator systems. Two to 6 mg/l of chlorine applied for 20 minutes killed 99.99 percent of all three indicator bacteria, but total coliforms showed aftergrowth in 24 to 72 hours. The authors concluded that fecal coliforms, rather than total coliforms were a more realistic microbial indicator of pollution.

The third article based on the work in the same Cincinnati study area concerned only the bacteriological aspects of storm water runoff [7]. As well as the study area used in the first two articles, suburban business district and agricultural land runoffs were also studied. Data given indicated the changes in bacterial composition of the storm water during the four seasons of the year. Variations for total coliforms, fecal coliforms and fecal streptococci were given, as well as Fc/Fs ratio and percent fecal coliforms. This study concluded that the major contamination of rainwater occurs from contact with the polluted land environment. Fecal contamination is derived from fecal material deposited by cats, dogs, rodents, etc., with fecal coliforms to fecal streptococci ratio generally less than 0.7.

The ratio for man is 4.4 and for domestic sewage, 4.0. Bacterial survival in storm water was studied and indicated that organisms persisted at higher levels for winter studies ($10^{\circ}C$) than they did for summer studies ($20^{\circ}C$). Salmonella Thompson was isolated in one storm sample at a level of 4500/100 ml. This sample came from the business district, and total coliforms for the sample involved were 3 800 000.

Another area in which separated storm water was studied was Washington, D.C. [8]. This study involved a 118-hectare (265-acre) site, but no information has been given concerning its physical composition. This study reported much the same work as the above, but also attempted to show how the various constituents of the wastewater changed during the course of the storm, and to translate the various values into actual amounts of the measured parameters reaching the rivers by this means. Results of chemical and bacteriological tests on storm water from this area were as follows:

pH - varied from 7.2 to 6.0, average 6.5,

SS - varied from 130 to 11 280 mg/l, average 1697,

COD - varied from 29 to 1514 mg/l, average 335,

BOD - varied from 3 to 90 mg/l, average 19,

Total coliforms - varied from 420 000 to 5 800 000, average 2.8×10^6,

Fecal coliforms - varied from 240 000 to 5 040 000, average 2.4×10^6,

Fecal streptococci - varied from 1000 to 49 000, average 17 200,

Phosphates - varied from 0.2 to 4.5 mg/l, average 1.3,

Nitrogen - varied from 0.5 to 65 mg/l, average 2.1.

In Madison, Wisconsin, a study of a 50-hectare (123-acre) area of the city was conducted, the subject area being composed predominantly of residential housing [9]. Rainfall events were monitored during the period from September 1970 to July 1971, and the average chemical concentrations were reported as follows:

Ammonia Nitrogen	0.45 mg/l,
Nitrate Nitrogen	0.60 mg/l,
Organic Nitrogen	3.5 mg/l,
Dissolved Phosphorus	0.57 mg/l,
Total Phosphorus	0.98 mg/l,
Total Solids	280 mg/l.

A study has been reported which deals with the quality of urban runoff and its effect on local streams, although this study was done on an open watercourse and not on a sewer [10]. Work done in Durham, North Carolina, in 1968, consisted of water samples taken at the conjunction of a series of open channels which provided drainage for a 415-hectare (1069-acre) area of the city. Virtually all of this area was built up and contained all types of districts, from part of the central business core, to an expressway under construction, to large areas of flood plain. Estimates were made of the contributions of

pollutants from the various types of subareas, showing how these contributions varied with the land use, with particular emphasis on lead.

Following are the results of tests on drainage from the entire area:

BOD - varied from 2.2 to 232, average 31.3 mg/1,
COD - varied from 40 to 660, average 224 mg/1,
Total solids - varied from 274 to 13 900, average 3930 mg/1,
Volatile Total Solids - varied from 20 to 1110,
average 426 mg/1,
Lead - 0.10 to 1.85, average 0.67 mg/1,
Chloride, as NaCl - 3.0 to 390, average 18 mg/1,
Total Phosphate - 0.15 to 2.50, average 0.55 mg/1,
Fecal Coliforms - 3000 to 1 900 000, average 248 000/100 ml.

This study concluded that the BOD contribution from urban land runoff was approximately the same as from the effluent from a secondary treatment plant, and that the contribution of lead to the runoff varied in direct proportion to the area of paved parking surfaces. This would seem to indicate that lead comes almost exclusively from the operation of automobiles.

Further work in the Durham, N.C., drainage area by Colston and Tafuri [11] in 1972 produced similar results but went further than the original 1968 work by comparing surface samples taken near the bottom of the watercourse being studied. Several equations were developed which tried to describe the runoff rate in pounds per minute for various pollutants at various times after rainfall had begun. Twenty-two pollutants were measured, with the range of concentrations similar to the 1968 work. In only one case, calcium, was the concentration of the pollutant higher at the surface than at the bottom, and only a 4% variation was noted. Surface concentrations were mostly between 70 and 90% of the lower level concentrations, but no information was given about the depth of the water at the time of sampling.

Canadian studies on urban runoff have been performed in only a few places. In Windsor, Hartt [12] studied the runoff from a 36-hectare (89-acre) residential and park subdivision in 1971, to determine the

seasonal variations in 19 parameters. Following are some of the results of Hartt's study.

Parameter	Annual Mean	Range
Conductivity, µmhos/cm	220	30 - 1650
pH	7.35	6.30 - 8.70
Suspended Solids, mg/l	305	2 - 4122
Alkalinity, mg/l	106	8 - 232
Total Hardness, mg/l	211	48 - 585
Chloride, mg/l	110	4 - 2580
Orthophosphate, mg/l	0.98	0 - 34
Sulphate, mg/l	106	32 - 325
Ammonia, mg/l	0.087	0 - 1.80
Nitrite, mg/l	0.09	0.01 - 0.53
Nitrate, mg/l	1.40	0.05 - 6.30
BOD, mg/l	12	2 - 52
Total Coliform/100 ml	2 405 800	1400 - 17 750 000
Fecal Coliform/100 ml	8760	0 - 230 000

In order to explain the great differences he found in seasonal pollution loadings, the author also investigated the rainfall runoff coefficient and determined that it varied from 0.84 in the winter to 0.14 in the fall. Pollutional loadings for ten parameters are given in pounds per acre.

Two other studies have been carried out on related areas. In Ottawa, Warnock [13], studied the quality of water reaching a single catch basin on the campus of the University of Ottawa and concluded that "BOD, suspended solids, and dissolved solids, are the primary pollutants of concern from this source. These quantities tend to decrease rapidly as a particular rain storm progresses, however". In Halifax, Waller [14] investigated the role played by several factors such as street maintenance, catch basins, etc., in polluting rainwater as it flowed to the storm sewers, again by sampling the water at the catch basin.

3 DISCUSSION OF THE LITERATURE REVIEW

The various references given in the literature review are summarized in Table 1. This table is based on a similar table in reference [18], with the addition of other references cited in this paper.

From this table and the summaries of the various articles given in the preceding pages, it can be stated that research work in the field of the water quality of urban drainage has been limited to only the last six or eight years. Prior to about 1970, work appears to have been carried out only in the various European references, together with Detroit and Cincinnati. Canadian work appears to have been limited to Windsor, Ottawa and Halifax, with the work in Windsor being the only study similar in nature to that reported here.

Several difficulties are encountered when reviewing the literature in this field. One is the varying number of parameters reported, a second is the terminology used, and a third is the various kinds of values presented.

The first 12 references, which were studies similar to this one, reported on almost 50 different parameters, although it can be safely assumed that several of the items refer to the same parameter but are expressed differently. Eleven studies reported on BOD, eight on suspended solids, six on COD, and the rest of the parameters were reported in five or fewer references. This makes meaningful comparisons for some values determined in the East York study very difficult since there are so few references with which to compare. Lead, for instance was reported only twice, phenolic compounds only once, and chlorides only three times. These three parameters were regularly measured in the East York work, and only chlorides were reported in other studies often enough to make comparisons possible. Even in this case, however, most other studies on chlorides were associated with studies of winter salting programs and the sampling points were rarely in storm sewers. This could make direct comparisons with East York work meaningless.

In many cases terminology is not a problem. BOD, for example is a well-known parameter, and tests and reporting methods are standardized enough that the results convey the proper impressions to the reader.

TABLE 1. COMPARISON OF STORM WATER QUALITY FROM OTHER STUDIES

LOCATION		BOD (mg/l)	COD (mg/l)	Total Solids (mg/l)	Volatile Solids (mg/l)	Suspended Solids (mg/l)	Total Phosphate (mg/l)	Coliforms (MPN/ 100 ml)*	Chloride as NaCl (mg/l)	Reference
Windsor, Ontario	Mean	12	-	-	59	305	0.98	-	110	[12]
	Range	2-52	-	-	0- 350	2- 4122	0-34	-	4-2580	
Washington, D.C.	Mean	19	335	2166	302	1697	1.3	600000	-	
	Range	3-90	29-1514	338-14600	12-1004	130-11280	0.2-4.5	120000-3200000	-	[5]
Madison, Wisc.		-	-	-	-	280	0.98	-	-	[6]
Detroit, Mich.	Mean	28	-	-	218	2080	5.0	-	-	
(1965)	Maximum	62	-	-	570	11900	16.4	-	-	[3]
Durham, N.C.	Mean	14.5	179	2730	298	-	0.58	30000F	12.6	
(urban storm water)	Range	2 →232	40- 600	274-13800	20-1110	-	0.15-2.50	7000- 86000F**	3.0 - 390	[7]
Cincinnati, Ohio	Mean	17	111	-	-	227	1.1	-	19.8	
(urban storm water)	Range	1-173	20- 610	-	-	5- 1200	<0.02-7.3	500- 76000F	5.0 - 705	[4]
Cincinnati, Ohio (rainfall)	Mean	-	16	-	-	13	0.24	-	-	
Coshocton, Ohio	Mean	7	79	-	-	313	1.7	-	-	
(rural storm water)	Range	0.5- 23	30- 159	-	-	5- 2074	0.25-3.3	<2- 56000F	-	
Coshocton, Ohio (rainfall)	Mean	-	9.0	-	-	11.7	0.08	-	-	
Detroit, Mich. (1949) (urban storm water)	Range	96-234	-	310- 914	-	-	-	25000- 930000T	-	[2]
Seattle, Wash. (urban storm water)		10	-	-	-	-	4.3 max.	16100 F max.	-	[1]
Stockholm, Sweden	Median	17	188	300	90	-	-	4000 F		
(urban storm water)	Maximum	80	3100	3000	580	-	-	200000 F	-	
Pretoria, South Africa (residential/park/ school)		30	29	-	-	-	-	240000 F	-	[1]
(business and flat area)		34	28	-	-	-	-	230000 F		
Oxney, England	Maximum	100	-	-	-	2045	-	-	-	[1]
Leningrad, USSR		36	-	-	-	14541	-	-	-	[1]
Moscow, USSR	Range	18-285	-	-	-	1000- 3500	-	-	-	[1]

* F = fecal; T = total

** Range of means for 17 storm series for Durham, N.C.

Note: Material in this table is based on a similar table in reference [18], with some additions.

Other parameters are not so standardized, with variations in what would appear to be easily documented parameters. Phosphorus appears to cause the most problems when reporting results and it has been described under the following headings:

Phosphorus, as P, Soluble
Phosphorus, as P, Total
Total Phosphates as PO_4
Soluble PO_4
Total PO_4
PO_4 (Total Soluble as PO_4)
Phosphates
Dissolved Phosphorus
Total Phosphorus
Total Phosphate
Orthophosphate

It can be assumed that total phosphates as PO_4, total PO_4, and total phosphate all refer to the total amount of phosphate present in both soluble and insoluble forms, but without further inquiry of the authors of the various papers, some element of doubt must remain.

A study of the various values reported presents another problem to the reader trying to glean some information from the literature. Values are reported as maximums, mean, or median values, maximums and medians, or maximums and minimums.

The maximum and minimum values by themselves appear to be of limited value, but in combination with the time between maximum and minimum occurrences these figures could yield valuable information as to the type of treatment required for this water. Median values appear to be of limited use when considering treatment methods, since they are bound to change depending on the number of samples averaged, the time period over which the samples are taken and the frequency of sampling. Obviously a sampling period including only the initial "first flush" of storm water will yield a far different median value than the same storm sampled long after the first flush has passed, when concentrations have

declined to a small percentage of the peak value. For purposes of comparison with other work, however, the median value would be beneficial since it gives a value more representative of the overall water quality of the runoff than maximums or minimums.

In this report the maximum values of concentration, and mass loading, a term discussed later, and the flow weighted mean are given in tabular form and the results of all testing, showing both maximum and minimum values and the time between occurrences, are shown in the appendix graphs.

4 EAST YORK STUDY

4.1 Background to the Study

The combined sewer areas in the Borough of East York are separated into two main areas. The northerly section comprises most of the residential area of the former Town of Leaside. The area between Bayview Avenue and Laird Drive, south of Eglinton, is served entirely by combined sewers, and about one-half of the area north of Eglinton is the same. Virtually all of the storm water from this area flows to the North Toronto Pollution Control Plant south of Millwood Road near the Leaside Bridge, via Laird Drive or the City's North Toronto Trunk Sewer. Here the dry-weather flow is treated and any excess is diverted to the Metro Trunk Sewer System and is conducted to the Ashbridges Bay plant. Storm overflows at North Toronto allow storm water to flow directly into the Don River.

The southerly and larger combined sewer area in the Borough is the section of the former Township of East York south of the Don River and Massey Creek. All of the combined sewers in this area flow to two outlets, one north of Cadorna Avenue, formerly served by the Todmorden Sewage Disposal Plant, and the other through what is now Cedarvale Park, just east of Woodbine Avenue, formerly served by the Danforth Park Sewage Disposal Plant. Both of these disposal plants were taken out of service when the Metro Toronto Trunk Sewers were built in the late 1950's. The original overflows remained, however, and the connections from the combined sewer systems to the new Metro trunk were simply the extensions of the connections from the sewer systems to the treatment plants. The volumes of water which can be overflowed to the river at these locations can be imagined when one considers the sizes and capacities of the pipes involved.

At Cedarvale Park the trunk combined sewer is 167 cm (66 inch) in diameter with a capacity in the range of 850 litres per second, while the connection to the Metro Trunk Sanitary Sewer is 38 cm (15 inch) in diameter with a capacity of about 72 litres per second. The Cadorna Avenue trunk combined sewer is 244 cm (96 inch) diameter with a capacity of about 1980 litres per second, while the connection to the Metro Trunk

Sanitary Sewer is 40.5 cm (16 inch) in diameter with a capacity near 96 litres per second. The two connecting pipes were originally designed to carry a volume equal to $2\frac{1}{2}$ times the dry-weather flow.

In 1963 the former Township employed the firms of Gore & Storrie, and Proctor and Redfern Limited to investigate storm separation in the combined areas of the Township. The reports were completed and construction of the three main outfalls were recommended and approved. The easterly outfall at Barrington Avenue was completed in the spring of 1965, and the westerly outfall, west from Broadview Avenue at Nealon Avenue, was completed by the early fall of 1965. The third outfall, a somewhat more complicated project, was completed, north from O'Connor Drive near Coxwell Avenue, by late summer of 1966. Following construction of the outfalls, sewers were extended along the adjacent streets until by 1972 some 80 hectares (200 acres) of combined sewer area had been separated.

4.2 Description of the Drainage Areas

Two of the three separated areas were selected for the study (Figure 1), those served by the outlet north of Barrington Avenue and the outlet west from Broadview at Nealon Avenue. The third outfall drains a small combined area and includes an overflow from the combined sewer to the storm sewer, and was ruled out for any work. The Broadview Avenue storm sewers originally included four cross connections to relieve any surcharge on the combined sewers, but as the storm separation program continued the cross-connections were judged to be unnecessary and were blocked up several years ago. The Barrington area never had any cross- connections of any sort.

The Broadview drainage area is a long, thin one and is illustrated in Figure 2. The area is predominantly single family residential, with four high-rise apartment buildings on Broadview near Mortimer and several on Gowan, Cosburn, and Gamble. There is a supermarket with parking lot at Westwood Avenue, and other nonresidential activities on Broadview include an automobile dealer, two service stations, a take-out food store and several small neighbourhood stores. The rest of the area

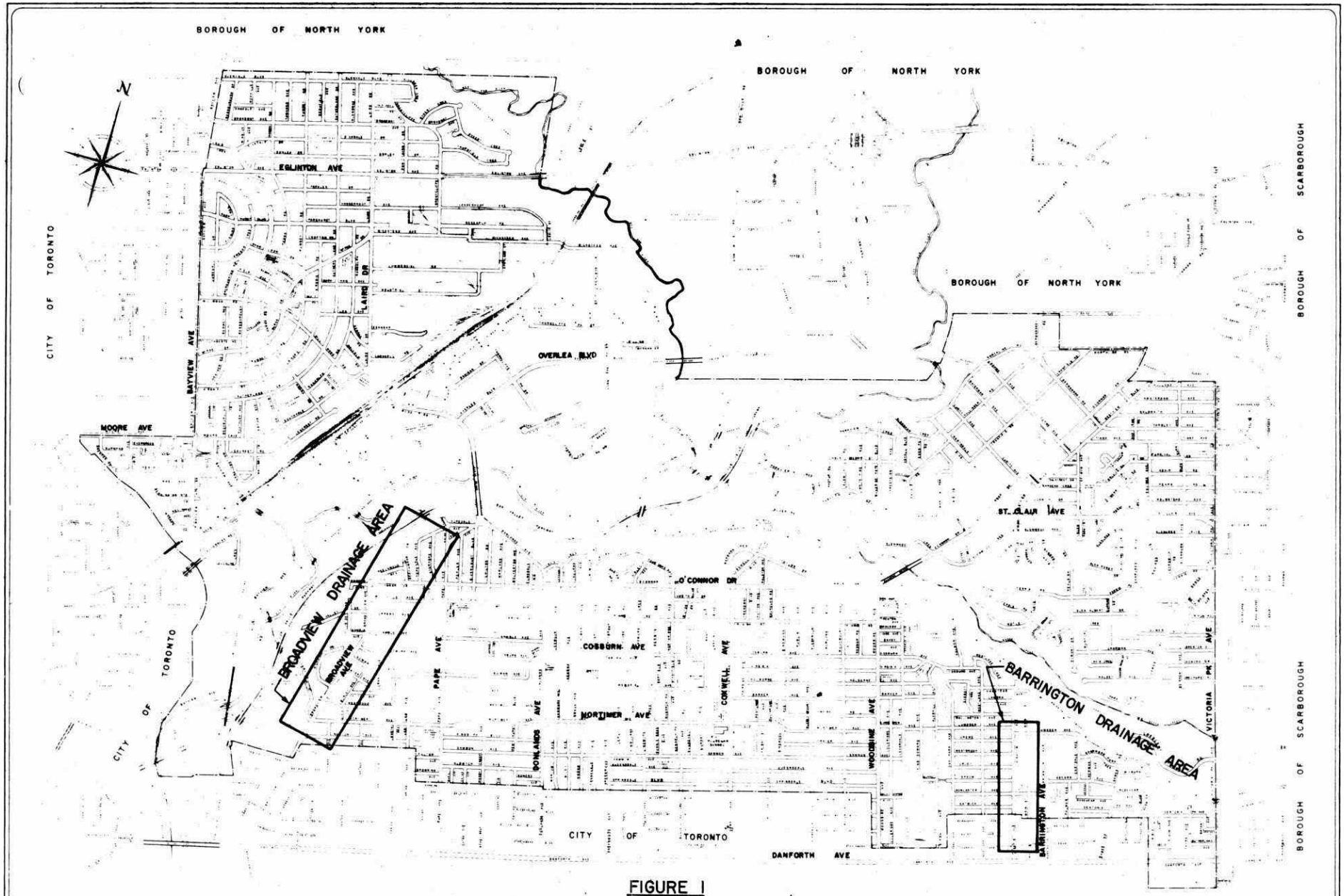

FIGURE I

BOROUGH OF EAST YORK

LOCATION OF DRAINAGE AREAS

SCALE: 1 centimetre = 240 metres

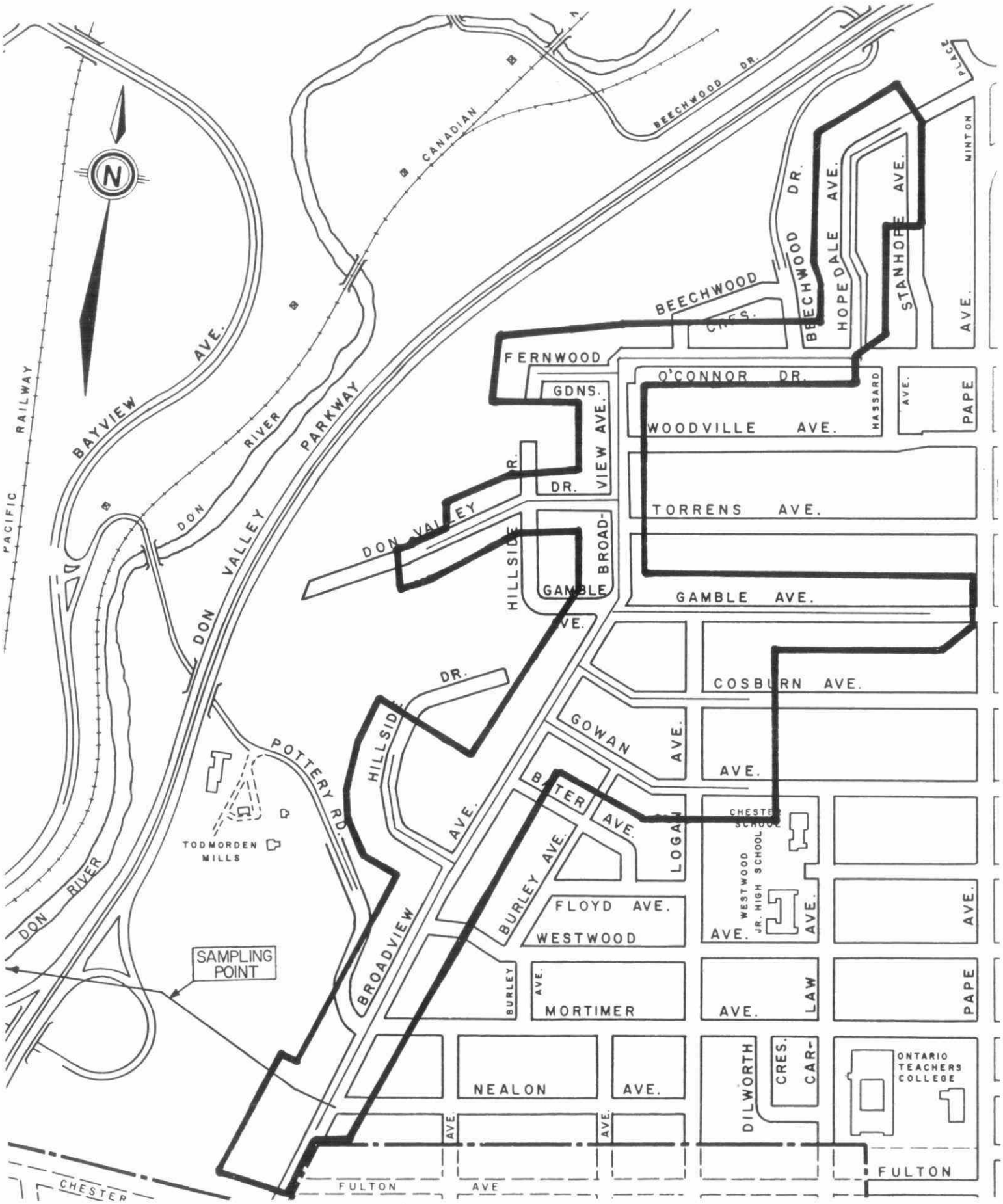

FIGURE 2 — BROADVIEW DRAINAGE AREA

SCALE: 1 centimetre = 60 metres

is composed of residential housing, some smaller, older apartments, and three 'Grand Ole Houses' now used as institutions.

The total area drainage to the outfall west of Nealon Avenue is 25.3 hectares (62.6 acres). All road catch basins in the area are connected to the storm sewer as are the storm services from the high-rise apartments and the supermarket. With very few exceptions the roof drainage from all of the houses is still connected to the old combined sewers. Table 2 gives a breakdown of the drainage area into its component areas.

All storm sewers are connected to the trunk sewer on Broadview which flows south to Nealon. Here the storm water falls down a 29 metre deep dropshaft, then is conducted to the Don River via a 244 cm diameter sewer and a 3 metre by 1.8 metre box culvert. The sampling point for the study is located near a manhole about 200 metres from the river, at the point where the 3 x 1.8 box culvert changes to the 244 cm circular storm sewer which was tunnelled under the Don Valley Parkway. Buildings in this drainage area vary in age from 80 or more years old to new high-rise. The single family houses include some originals from the former Village of Todmorden, many from the 1920's, and some small subdivisions from the early 1940's.

The Barrington area is much more compact and includes part of the City of Toronto. This area is illustrated in Figure 3, and is entirely single family residential housing except for five or six corner stores. All the houses in the area are 50 to 70 years old with very few exceptions, and virtually all their roof drains are connected to the old combined sewer. The separated drainage area flowing to this site is 22.7 hectares (56 acres) and is broken down in Table 2. The storm sewers on Chisholm Avenue and Main Street flow to the trunk sewer on Lumsden, which in turn carries the flow to a 10 metre deep dropshaft at the end of Barrington Avenue and then northward to Massey Creek, through a 152 cm circular pipe. The sampling point for this study was located just upstream from the dropshaft in the trunk sewer on Lumsden Avenue. All street catch basins in both East York and the City of Toronto are connected to the new storm system.

TABLE 2. DESCRIPTION OF DRAINAGE AREAS

Area	Gross Area		Area of Buildings not Connected to Storm Sewer System		Net Area Contributing to Storm Runoff		Area of Roads and Public Sidewalks		Area of Buildings Connected to Storm Sewer System		Area of Parking Lots		Area of Lawns Private Walks and Driveways	
	hectares	acres	hectares	acres	hectares	acres	hectares	acres	hectares	acres	hectares	acres	hectares	acres
Broadview	25.3	62.6	3.3	8.1	22.1	54.5	5.2	12.9	2.1	5.2	0.8	2.0	14.0	34.4
Barrington	22.7	56.0	5.3	13.0	17.4	43.0	4.1	10.1	-	-	-	-	13.3	32.9

NOTE:

(a) All the areas shown for Broadview have been determined using topographic maps at a scale of 1:480.

(b) The areas shown for Barrington have been determined by using the 1:480 topographic maps to determine the various areas within East York. These maps are not available for the City of Toronto section and the gross area and area of roads and sidewalks in the City were determined using maps of 1:2400 scale. The area of buildings not connected was determined by projecting the ratio $\frac{\text{area of buildings in East York not connected}}{\text{gross area in East York}}$ over the gross drainage area.

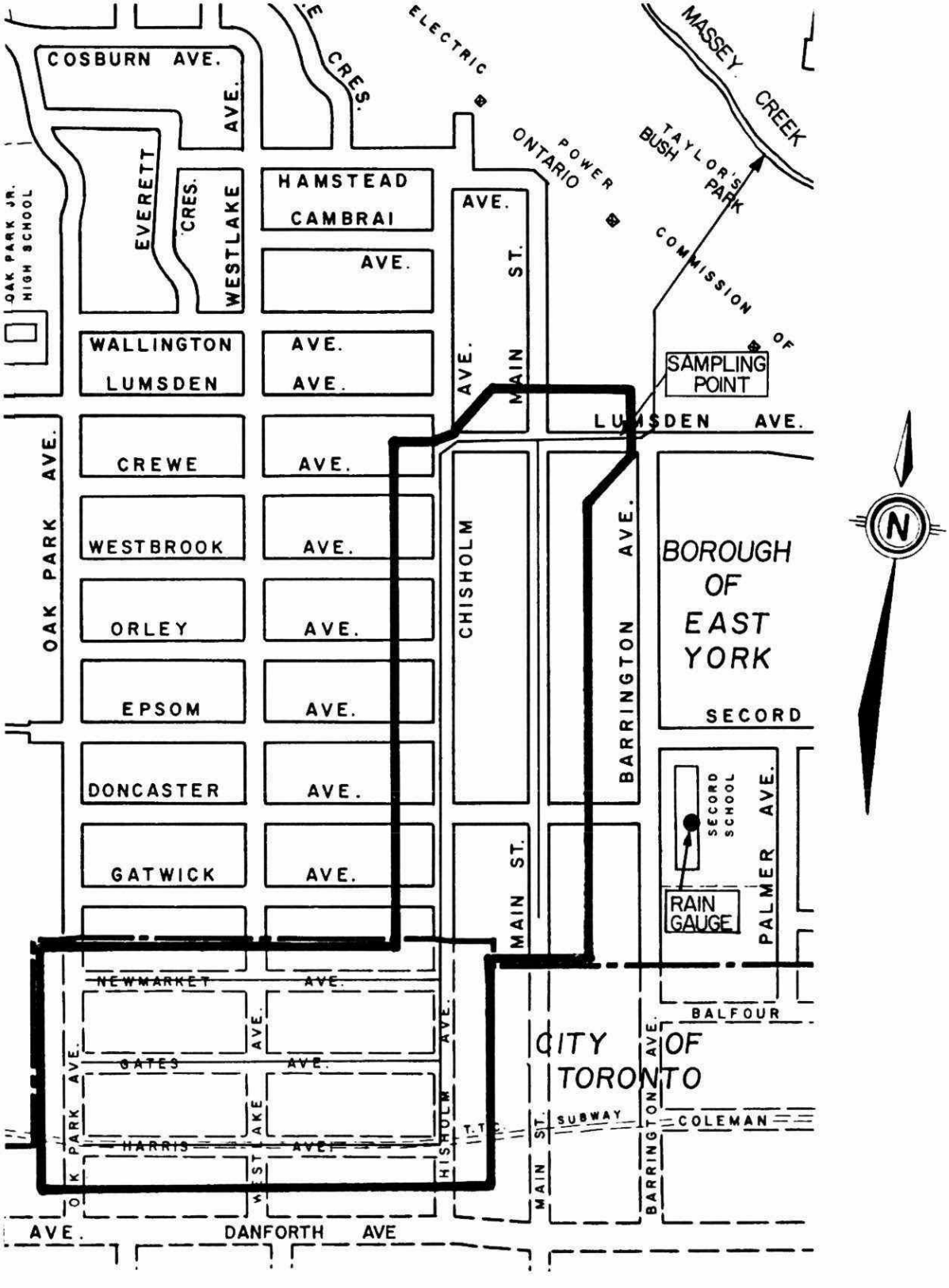

FIGURE 3 — BARRINGTON DRAINAGE AREA

SCALE: 1 centimetre = 60 metres

4.3 Geology

Most of the southerly areas of the Borough are underlain by the remains of beaches formed some 15 - 20,000 years ago by Lake Iroquois. In the western portion, which contains all of the Broadview drainage area, some 2 to 3 metres of silty fine sand lie directly on the blue clay till which is common to most of the Metro Toronto area. The water table is perched at the interface between the sand and clay and does not appear to penetrate into the clay. Pockets of topsoil up to 70 cm deep are frequently encountered below the present ground surface, which accounts for the extensive market gardening industry which flourished in the area before it was swallowed up by urban expansion.

The depth of sand over the clay increases towards the east, to a depth of about eight metres at Coxwell Avenue and in excess of 10 metres in the Barrington drainage area. Soil borings for the storm sewer system draining to the Barrington outfall were drilled to a depth of 10 to 12 metres, and revealed only a coarse to fine sand with no trace of the underlying clay till or the water table at these depths. Only one hole, on Chisholm Avenue near the South Borough limit, showed even a damp sand condition. All others were dry.

4.4 Sampling Equipment and Method of Operation

Both sites were provided with a weir to reduce the width of flow and enable more accurate flow records to be taken. The weirs were composed of aluminum plates placed vertically, 0.915 metres apart, and are illustrated in Figure 4. For both sites, the Canada Centre for Inland Waters performed model tests to determine flow curves. These curves enabled the sampling personnel to convert a single depth measurement into the correct flow rate at the time the sample was taken.

The Barrington Avenue site proved to be by far the more reliable and more work was done at this site than at Broadview. This was mainly because an electrical service was installed to the sampling point in the sewer, enabling electrical equipment to be used continuously. Broadview required battery operated equipment because of its remote location, with all the attendant problems regarding battery charging, lighting, etc. A tipping bucket rain gauge, supplied by the Canada

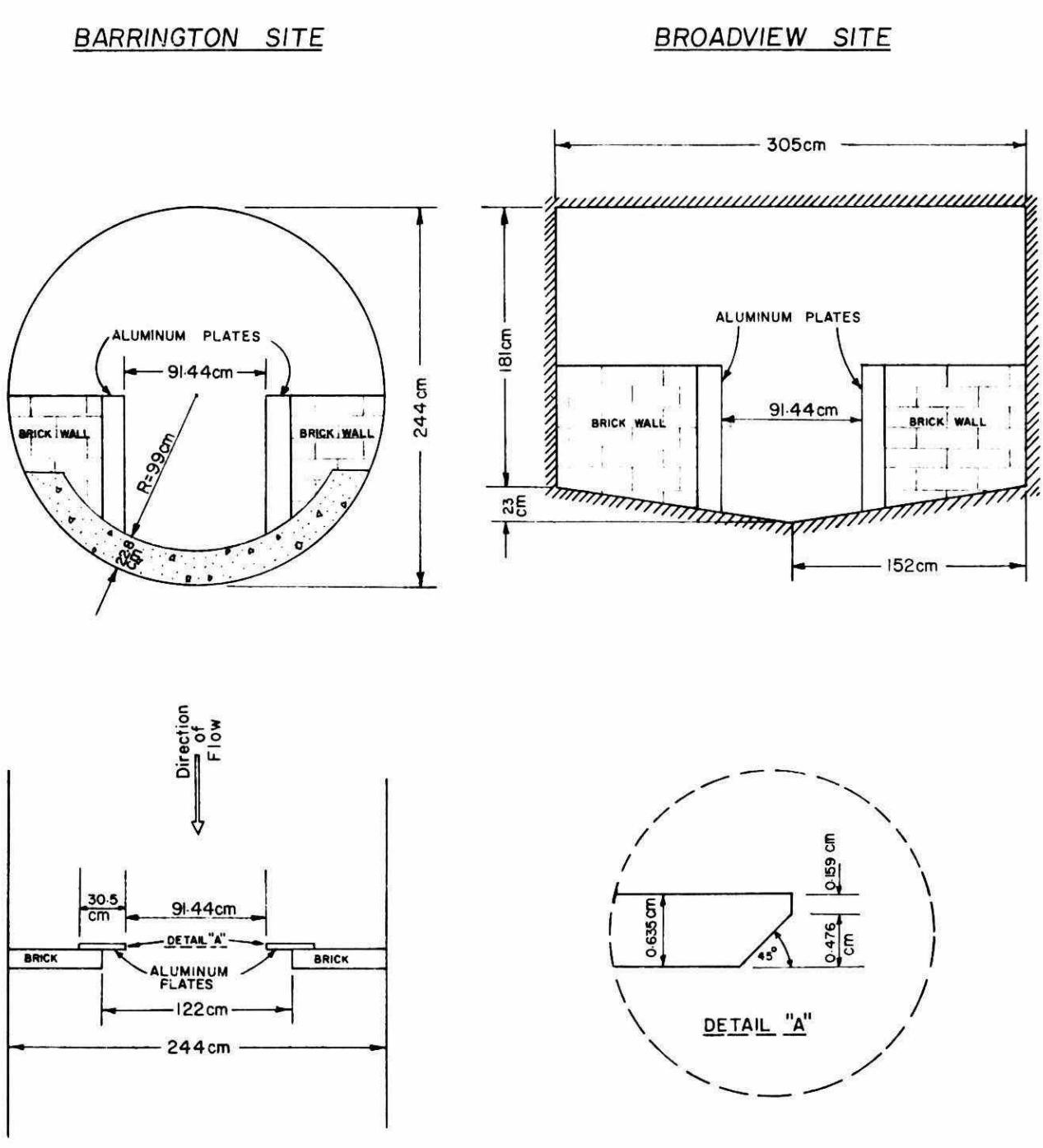

FIGURE 4 FLOW METERING INSTALLATIONS

Centre for Inland Waters, was located on the roof of Secord School, about 300 metres south of the Barrington sampling point. Water level in the sewer was recorded by a Wesmar sonic flow recorder, recording on a Bristol 10.16 cm (4 inch) wide strip chart. The recorder was set to indicate a surface variation of 76.2 cm in the 10.16 cm width of the chart. This equipment was owned by the Borough. Water samples were taken manually as well as automatically by a Sigmamotor Model WM-4-24 Automatic Water Sampler. The sampler was also owned by the Borough.

At the Broadview site a Leupold & Stevens flow recorder, supplied by the Canada Centre for Inland Waters, was used; this is designed for recording water elevations in a river. This device operates on a float which rises and falls with the water level, and has the great advantage of recording rainfall on the same chart as the water level. In this application, however, the equipment had to be adapted to function in a box culvert with less than two metres of headroom. Since there was no secure site for the rain gauge, the area being a public park, the rain gauge was not installed at this site and no rainfall data is available. The float was suspended from a pully fastened to the culvert roof upstream of the weir, and rose and fell inside a cage formed by three reinforcing rods. This arrangement proved to be sensitive and stable enough that the float was not disturbed by the speed of the water. The only problem was that the three reinforcing rods caught debris which prevented the float from settling back to the culvert floor, and affected its rise at the start of a storm if the debris was allowed to accumulate. Water levels were transferred from the float to the recorder located downstream of the weir via a wire and pulley system. Power for the recorder was provided by a 12 volt truck battery feeding a DC-AC power inverter, which converted the 12 volt DC power to 110 volt AC. This arrangement would power the recorder and a 25 watt electric light for eight to ten hours, and the recorder alone for almost two days.

The method of operation at both sites was similar. At the start of a rainfall event the operator arrived and immediately turned on the automatic water sampler. Samplers were timed to take a sample every

half-hour and had capacity for 24 samples over a 12 hour period. Manual samples were then taken, initially every five minutes for two hours, then reduced to every 15 minutes for all work done during 1975. The personnel taking samples did not realize until after the study was complete that eight samples taken every 15 minutes resulted in one hour and 45 minutes of sampling, and not two hours as originally planned. Bacteriological samples were taken every 15 minutes for the two hour period. Following the sampling period the bottles for chemical analysis were stored on the site, and the bacteriological samples removed for refrigeration. The next day the crew returned, removed the samples from the automatic sampler and took all samples, both bacteriological and chemical, to the Ontario Ministry of the Environment Laboratory at Highway 401 and Islington Avenue for analysis. The water samples taken by the automatic samplers were 450 ml samples, and the machines required seven minutes pumping time to fill the plastic sample bottles to this volume. Chemical samples were taken in 900 ml (32 oz.) glass bottles and bacteriological samples in 170 ml (6 oz.) bottles, received from the Ontario Ministry of the Environment Laboratory in a sterilized condition.

At the laboratory during 1973 and 1974 the samples for chemical analysis were separated into two groups with alternate bottles in each group, and different tests were run on the two groups. This produced results for the various parameters at ten minute intervals. In 1975 the manual samples were taken 15 minutes apart, and one set of tests run on the manual samples and the other tests on the samples from the automatic samplers. Using this method results for all parameters tested during 1975 were determined from both manual samples over a one hour and 45 minute period, and automatic samples, over a period determined by the length of runoff time, up to 12 hours.

4.5 Sampling and Testing Program

The actual testing program was run on a day-to-day basis by Borough of East York personnel under the general supervision of the Ministry of the Environment. The Ministry determined the time intervals between samples, and changed the sampling frequency from 5 minutes to 15 minutes as data became available and early results tabulated. In the

same way the parameters to be measured were selected by the Ministry, and were tailored to suit the volume of sample taken by one manual sample bottle and one automatic sample bottle. Since each test required a certain volume of water, those tests which required large volume had to be done on manual samples, while the automatic sampler bottles, being smaller, were reserved for low-volume tests. Eventually the parameters measured were reduced in number so that the entire series of tests could be run on both manual and automatic samples. This enabled the results of all parameters to be extended past the manual sampling period.

Some parameters were included because the Ministry of the Environment was most interested in the contribution of these parameters from urban storm drainage to the receiving waters. These included the two nutrients, nitrogen and phosphorus, which are the controlling elements in the growth of algae and other aquatic plant life. Lead, because of its effect on fish life and the food chain in general, and chlorides, because of the recent interest in the environmental effects of winter road salting programs were also included. Other tests such as BOD, COD, and suspended solids were included because of their general usefulness in describing water quality. Conductivity, hardness, alkalinity, pH, and TOC could also be included in this category. The remainder of the parameters, sodium, phenols, potassium, and sulphates, were included because they were found in significant amounts in the earliest samples, and also because, as explained earlier, the volume of water required to test for these parameters was available after the other tests had been completed.

Table 3 shows the various sampling dates and the parameters measured on each date, and indicates that 24 parameters were measured. In addition, iron was measured on samples taken on November 28, 1973 from both outfalls, and petroleum hydrocarbons were measured on samples from both outfalls taken on November 20, 1974. Consequently 26 parameters were measured over the period of this study.

In addition to the 24 sampling programs mentioned in Table 3, several samples were taken from both Broadview and Barrington in late 1973 and early 1974 during runoff periods. These samples were obtained

TABLE 3. SAMPLE DATES AND PARAMETERS MEASURED

PARAMETER \ DATE	BARRINGTON																			BROADVIEW				
	May 8, 1974	May 16, 1974	June 10, 1974	June 13, 1974	June 18, 1974	July 29, 1974	September 12, 1974	September 17, 1974	September 25, 1974	November 5, 1974	November 20, 1974	January 29, 1975	August 21, 1975	September 11, 1975	October 1, 1975	November 7, 1975	December 30, 1975	January 26, 1976	February 18, 1976	September 17, 1973	November 21, 1973	July 29, 1974	November 5, 1974	November 20, 1974
BOD	24	12	24	12	24	24	12	20	12	26	27	18	8	11	29	25	8	8	8	22	21	11	12	11
Suspended Solids	24	12	24	12	24	24	12	20	12	12	27	18	8	18	29	27	8	8	7	22	21	11	12	11
Dissolved Solids	24														21					22	21			
Total Solids: Dried	24														14					22	21			
Total Solids: Ashed																				22	21			
Total Solids: Loss																				22	21			
COD	24	12	24	12	24	24	12	20	12	26	27	8			8	28	8	8	8	22	21	11	12	11
TOC				12	22	24			12	26		18										11	12	
Ammonia	19	12	24	12	24	17	12	12	12	12	11	8	8	8	29	28	8	8	8	23	21	11	11	11
Kjeldahl	19	12	24	12	24	19	12	12	12	12	11	8	8	8	29	28	8	8	8	23	21	11	11	11
Nitrite	19	12	24	12	24	17	12	12	12	12	11	8	8	8	29	28	8	7	8	23	21	11	11	11
Nitrate	19	12	24	12	24	17	12	12	12	12	11	8	8	8	29	28	8	7	8	23	21	11	11	11

TABLE 3 (Continued)

PARAMETER \ DATE	BARRINGTON																			BROADVIEW				
	May 8, 1974	May 16, 1974	June 10, 1974	June 13, 1974	June 18, 1974	July 29, 1974	September 12, 1974	September 17, 1974	September 25, 1974	November 5, 1974	November 20, 1974	January 29, 1975	August 21, 1975	September 11, 1975	October 1, 1975	November 7, 1975	December 30, 1975	January 26, 1976	February 18, 1976	September 17, 1973	November 21, 1973	July 29, 1974	November 5, 1974	November 20, 1974
Total Phosphorus	19	12	24	12	24	19	12	12	12	12	11	8	8	8	29	28	8	8	8	23	21	11	11	11
Soluble Phosphorus	19	12	24	12	24	17	12	12	12	12	11	8	8	8	29	28	8	7	8	23	21	11	11	11
Phenols	24	12	24	12	24	24	12	20	12	26	11	18	8		8	28	8	8	8			11	12	11
Chlorides	17	12	24	12	24	19	12	12	12	12	11	8	8	11	8	28	8	8	8	23	21	11	11	11
Sodium	20	12	24	12																17	21			
Potassium	20	12	24	12																21	21			
Lead	19	12	24	15	23		19	19	19	26	11	17	8		8	17	8	8	8	21	21	11	12	11
Sulphate	23	12	24	12									8							15	21			
Conductivity	24		24	12	24	18	12	12	12	12	11	8	8	19	7	28	8	8	8	23	21	11	11	11
Hardness	15		12	24	12															23	21			
Alkalinity	24	12	24	12																23	21			
pH																				23	21			

at various times during the runoff period while the parameters present and their extent were still being determined. Some results are of interest and are mentioned in Table 6 (Appendix A), and in the discussion of the results.

During late April and early May 1974, samples were taken on three occasions and tested for herbicides and pesticides. Results of these tests are included in this report. Heavy metals were tested briefly during the winter of 1975-76 and these results are included.

5 RESULTS

5.1 General Comments

Results of the study are summarized in Tables 6, 7, 8 and 9 in Appendix A. Table 6 indicates the maximum value determined in the 24 sampling events for the parameters which are specifically mentioned in Metro Toronto Bylaw 2520, given in Appendix B and discussed later. Table 7 indicates the maximum concentrations determined for the remainder of the parameters monitored. Table 8 shows the maximum "Mass Loading" which was determined for the various parameters during each of the 24 rainfalls, and Table 9 indicates the flow weighted mean for each parameter for each event and the actual mass of material conveyed to the river during the sampling period.

Appendix A graphically presents data for the storm of September 11, 1975. The figures show rainfall, pollutant ion concentration, measured flow, and the mass loading rate plotted against time, for the following constituents: BOD, suspended solids, Kjeldahl nitrogen, free ammonia nitrogen, nitrite nitrogen, total phosphorus, soluble phosphorus, and chloride. Data is available for other storms, on file with the Ontario Ministry of the Environment (address in Appendix A).

All results in Tables 6, 7 and 8 are maximum values. The flow weighted mean in Table 9 is calculated by dividing the total flow measured into the total mass measured, and is expressed in milligrams per litre.

The term "Mass Loading" is derived from the Washington study [8], and is a factor indicating the rate at which the flow is contributing the parameter in question to the receiving water. The actual mass of the parameter contributed during any storm can be obtained simply by measuring the area under the mass loading graph in the appendix. Other units used in the various reports were pounds per acre and pounds per curb mile, with their respective metric equivalents being kilograms per hectare and kilograms per curb metre. The kilograms per hour factor was used in this report because it is deemed to be the most useful one of the three under consideration in that the other two can be obtained directly from it, but the reverse is not possible without all of the flow data.

Metro Toronto Bylaw 2520, "To regulate the discharge of sewage and land drainage in the Metropolitan Area", contains the regulations governing the quality of storm drainage in the Metro Toronto area. This bylaw specifies maximum concentrations for several parameters and states that water containing these parameters in excess of the stated concentrations will not be permitted to be discharged to sewers or watercourses in the area. Table 6 indicates the Bylaw 2520 limit for the eight chemical parameters included in both the bylaw and this study, together with the maximum concentrations recorded in the 24 sampling programs which were performed.

For more information on the subject of legislation governing the quality of discharges to rivers and watercourses in the Metro Toronto area, the reader is referred to Appendix B which contains a copy of Bylaw 2520 in its entirety.

5.2 Discussion

In addition to the information set out in Tables 6, 7, 8 and 9 and in the graphs in Appendix A, other parameters including petroleum hydrocarbons, pesticides and herbicides and heavy metals were measured briefly, with the following results.

	Broadview		Barrington	
	Sample 1	Sample 2	Sample 1	Sample 2
Gasoline	8 mg/l	6 mg/l	Trace	9 mg/l
Oil	5 mg/l	Trace	None	None

No other study has reported on petroleum hydrocarbons and only the samples indicated above were tested. Consequently no comparisons can be made and the results are included here only because they form part of this study. Metro Bylaw 2520 simply states that discharges to storm sewers shall not contain any gasoline. See Section 6 (b) in the Bylaw reproduced in Appendix B.

Heavy metals were tested on two occasions at Barrington and the results are given below.

TABLE 4. HEAVY METALS

Parameter	December 30, 1975 Concentration mg/l	December 30, 1975 Mass Loading kg/hour	February 18, 1976 Concentration mg/l	February 18, 1976 Mass Loading kg/hour
Zinc	0.61	0.054	0.46	0.0614
Copper	0.09	0.00796	0.07	0.00935
Nickel	0.03	0.00266	0.02	0.00267
Cadmium	<0.01	<0.00089	<0.01	<0.00134
Manganese	0.30	0.0266	0.16	0.0213
Chromium	0.11	0.0098	0.02	0.00267
Flow	24.6 litres per second		37.1 litres per second	

These samples were both taken early in the runoff period and would probably be representative of the maximum concentrations present, assuming the values declined as the runoff continued. Both events were in the winter but only December 30 was closely associated with road salting.

Herbicides and pesticides were investigated, with samples being taken on three occasions. The storm water was tested for the following four classifications:

1) organo-phosphate pesticides,
2) organo-chloride pesticides,
3) triazine herbicides,
4) chloro-phenoxy acid herbicides.

No trace was found of the following:

1) Triazine herbicides - Prop. - Azine
   - Atrazine
   - Prometryne
   - Simazine

2) Organo-phosphate pesticides

- Ethion
- Dichlorvos
- Mevinphos
- Phorate
- Ronnel
- Methyl Parathion
- Malathion
- Parathion
- Methyl Trithion

3) Organo-chloride pesticides

- Lindane
- Aldrin
- Heptachlor
- Hept. Epoxide
- Thiodan
- Dieldrin
- Endrin

4) Chloro-phenoxy acid herbicides

- Silvex
- 2, 4-DB

The following compounds were detected in the concentrations listed. All figures shown are in parts per trillion (ppt).

	Organo-chloride Pesticides				Chloro-phenoxy Acid Herbicides	
	DDE	DDD	DDT	PCB	2, 4-D	2, 4, 5-T
April 29, 1974	-	-	-	230	-	490
May 8, 1974	10	15	30	75	3,000	125
May 9, 1974	7	35	30	77	-	-

In the list above a dash indicates that none was detected. Some of the compound could have been present below the detection limit of the equipment used.

Very few winter samplings were obtained during 1973-74 or 1974-75. The winter of 1975-76 was much more severe than either of the previous two and sampling programs were conducted on three occasions following snowfalls. The influence of winter salting programs can be noted in most of these programs, particularly in the events of December 30, 1975, and January 26, 1976. Table 6 (Appendix A) indicates this

clearly by the high chlorides content in both events. These two also produced the highest COD and among the highest values for lead, phenolic compounds, Kjeldahl nitrogen, nitrates, and conductivity determined in a regular sampling program. It is also noteworthy that the sampling at Broadview on November 21, 1973, followed the first road salting of the winter by six days, and chloride levels had fallen almost into the normal range, although still high. The same appears in the results of February 18, 1976, wherein the chloride level had fallen to the level of some summer sampling programs. From this it can be inferred that salt is washed away fairly quickly, or at least takes a form which is retained in the environment, to be released later in the summer.

On February 12 and 13, 1974, following snowfalls totalling 18.5 cm in the previous week, the temperature rose well above freezing on two bright, sunny days. The result was runoff from melting snow which had been subjected to normal ploughing and salting operations. During these two days, water samples were taken from both outfalls and, while only eight samples are involved, the results are remarkable enough to warrant reproduction in Table 5, where both the concentrations and mass loadings are given. The flows in the sewers at the time of sampling were between 16 and 24 litres per second, and the contents of these eight bottles contained the highest readings found in the entire study for nine concentrations and five mass loadings, and the second highest readings for three concentrations and three mass loadings, as follows:

Highest concentrations recorded for

- Suspended Solids
- Dissolved Solids
- Total Solids
- Conductivity
- Sodium
- Chloride
- Sulphate
- Lead
- Alkalinity

TABLE 5. SNOWMELT SAMPLES, FEBRUARY, 1974

	CONCENTRATION				MASS LOADING			
	BARRINGTON		BROADVIEW		BARRINGTON		BROADVIEW	
	February 12, 1974	February 13, 1974	February 12, 1974	February 13, 1974	February 12, 1974	February 13, 1974	February 12, 1974	February 13, 1974
BOD	80	70	46	36	7.8	6.20	2.74	3.04
Suspended Solids	1570	560	440	410	139	49.6	24.5	34.7
Dissolved Solids	24300	8650	10380	10700	1630	582	612	900
Total Solids	25870	9210	10820	11110	1720	619	640	930
COD	850	460	300	200	75.3	40.7	17.9	16.9
Total Phosphorus	1.8	0.60	0.20	0.14	0.16	0.0531	0.0085	0.0119
Dissolved Phosphorus	<0.10	<0.04	0.02	<0.02	<0.0089	<0.00354	0.00085	<0.00169
Ammonia	0.50	0.80	0.20	0.10	0.0442	0.0708	0.0085	0.085
Total Kjeldahl Nitrogen	11	6.3	2.6	1.6	0.98	0.557	0.155	0.109
Nitrite	0.55	0.48	0.25	0.26	0.0487	0.0424	0.0149	0.022
Nitrate	1.5	1.3	4.5	4.5	0.133	0.115	0.268	0.381
Sodium	10800	3030	4040	3900	960	269	241	330
Potassium	8.6	7.8	11	7.8	0.717	0.690	0.66	0.66
Hardness	496	296	516	416	43.9	26.0	30.6	35.2
Alkalinity	492	177	227	234	43.5	15.8	13.5	19.9
Lead	0.32	0.21	4.3	2.5	0.380	0.222	0.0381	0.0178
Chloride	14000	5980	6140	4930	1240	436	365	502
Sulphates	200	200	240	160	21.3	14.2	11.9	16.9
Conductivity	38500	14000	19000	18000	-	-	-	-

NOTE: 1) All values are expressed in milligrams per litre for concentration and kilograms per hour for mass loading except conductivity which is expressed in micromhos per square centimetre.

2) Results shown in this table are from four single bottle samples.

Second highest concentrations recorded for

- COD
- Nitrate
- Hardness

Highest mass loading recorded for

- Suspended Solids
- Dissolved Solids
- Total Solids
- Sodium
- Chloride

Second highest mass loading recorded for

- Nitrate
- Lead
- Sulphate

These results are given to illustrate the degree to which runoff in separated storm sewers can deteriorate, and are probably the worst possible conditions experienced in these systems under normal operating conditions.

The effect on urban runoff of a series of rainfall events in a short space of time was one of the questions to be investigated during the study. The sampling program included two series of three storms, each within a period of two weeks, on June 10, 13 and 18 and on September 12, 17 and 25, 1974. Both series were preceded by a period of 10 to 12 dry days and rainfall during the time of the three events amounted to 5.10 cm in June and 2.52 cm in September, daytime temperatures for both periods remaining fairly constant in the low 20's. The May and June time period of 1974 was wetter than usual, with the Bloor Street weather observatory reporting about double the normal rainfall, while the August - September period was drier, with Bloor Street reporting 70% of normal rainfall.

The tables and graphs in the appendices illustrate a reduction in concentrations and mass loadings of many of the parameters during the

three storms, but the reductions are not consistent. The June storms show reductions but must be qualified by the following facts:

(a) The June 10 storm was a cloudburst in which over 2 cm of rain fell in a 10-minute period, then stopped completely, and

(b) the June 18 samples were taken well after the start of rainfall.

The September series must also be qualified because the eight days between the second and third samplings may have been too much time to allow the third sampling to be included. However, if the results of September are not taken as the third in a series, they can be used to illustrate the speed with which many of the parameters build up. Notice that many are higher on September 25, notably COD, phenols, chlorides and lead.

Mention must also be made of the effect of the June 10 downpour on the concentrations determined long after the rainfall had ceased. BOD in excess of 100 mg/l and COD in excess of 300 were measured up to $11\frac{1}{2}$ hours after the end of the heavy rainfall. Lead also remained comparatively high over the same period. Total and soluble phosphorus and potassium were all high over the period of manual sampling. It would appear that these parameters were stirred up by the intensity of the rainfall, whereas softer rainfall had not nearly the same effect.

Seasonal variations were another facet of urban runoff to be investigated in this study but unfortunately not enough events were sampled to draw conclusions. About the only observations to be made here are the high sodium and chloride levels of the winter, attributed to road salting, and an apparent trend towards higher BOD in the summer months and lower in the winter.

Another phenomenon associated with urban runoff is the "first flush". This has come to be defined as the washing out of the drainage area and sewer system as the storm and runoff continue, with consequent reductions in concentrations as time progresses. The presence or absence of the "first flush" is well illustrated in the graphs in Appendix A. If the definition as quoted above is used, and concentrations are to decline independently of the rainfall intensity, then the graphs show

the "first flush" to be nonexistent for most of the parameters studied. Comparison between flow and concentration lines on the graphs clearly indicate a correlation between the rainfall intensity and consequent flow rate, and the concentration for most parameters. This is clearly the case with suspended solids, for instance, and while individual storms may show a "first flush" for some parameters, other storms show the correlation with flow. Consequently, this study was not able to confirm the presence of a "first flush" phenomenon and can show it to be present consistently only in the soluble phosphorus graphs.

The effect of a long dry spell on runoff quality was investigated, and there appears to be evidence to support the contention that a long period with no rain will result in a "dirty" environment and consequent high concentrations in the first runoff at the end of the dry spell. The longest period without significant rainfall prior to a sampling program was the six weeks preceding the first sampling at Broadview on September 17, 1973, a period of 42 days during which temperatures reached as high as 32^{o}C. Maximum concentrations on this date were among the highest recorded, particularly for chlorides, sulphates and suspended solids. As mentioned before, the eight days between September 17 and 25, 1974, may have allowed sufficient dirt to accumulate to eliminate the 25th from the three sucessive storm investigations. Once again, however, the entire question of antecedent dry spells must be balanced against the intensity of the rainfall, since the June 10, 1974, event was preceded by 13 dry days, and the downpour of this date produced runoff characteristics different from the September 17, 1973 events. It is the writer's opinion, however, that the results of this study would tend to support the supposition that a period of dry weather will result in high concentrations in the runoff from the next rainfall event.

Should treatment of storm water ever be contemplated, one of the treatment methods to be considered would most likely be holding tanks. With this in mind, the various results of this study were reviewed to determine if there was any evidence as to whether or not this method of treatment would be at all effective. The assumption was made that any parameter which rises and falls in concentration in a manner

similar to the flow of water in the sewer would be associated with particulate matter in the water and could be reduced by settling. As mentioned under discussion of the "first flush", almost all of the parameters showed some correlation with flow, and would at least be reduced by this form of treatment. Suspended solids showed the closest correlation to the water flow as can be observed by looking at the appendix graphs.

In addition to the overall questions discussed in the preceding paragraphs, several parameters were investigated individually and the results are noted below.

(a) BOD - Our results did not agree with the observation of Burm et al [4] that "the BOD values did not vary greatly from season to season". Reference to Table 6 (Appendix A) will show that the maximum values of BOD occurred during the summer and fall, with definitely lower maximum readings in the winter and early spring.

Maximum values of BOD were also in excess of any other reported readings. Table 1 indicates only three studies reporting values in excess of 200 mg/l and none in excess of 300. Table 6 notes a high BOD reading of 320 mg/l and two others in excess of the highest North American values. The 260 mg/l value of June 10, 1974, could possibly be explained by the intense downpour which was previously mentioned, but no similar explanation is available for the July to November period of high maximums.

(b) Suspended Solids - Values for all solids factors, total, dissolved and suspended, were lower than many of the reports noted in Table 1. Our maximum of 630, exclusive of the snowmelt samples, was far below values for Detroit [4] and Washington [8]. This could be due to the lack of any major construction work in the two drainage areas, and the fact that virtually all of both areas is either sodded or paved. Verbal discussions with laboratory personnel indicated the lack of large particles such as sand in the samples tested at the lab, but the presence of a sand bar at a bend in the sewer near the test site indicates that some are present and settle out on the inside of the radius as the water flows around the bend.

(c) Chlorides - The presence of chlorides in urban runoff has been associated with road salting procedures during the winter. This study confirmed this association and also agreed with the work done by Oliver [17] in Ottawa. Highest values of chlorides were noted following road salting operations and were reduced considerably during the summer months. The June series of events indicated that chlorides could be washed out of the environment, with maximum value of 57 mg/l on June 10 decreasing to 5 mg/l on June 18. There would appear to be some evidence indicating that the environmental chloride content increases during a long dry spell, because the September 17, 1973 maximum of 152 mg/l was the highest value not associated with road salting, and occurred following a six week dry spell in the drainage area.

The relationship between sodium and chloride concentrations can also be used to indicate that both come from road salting operations. When the relationship between the two is in approximately the same ratio as their molecular weights, 23 : 35.5 or about 2 : 3, the source of both can safely be assumed to be salt. Following are some comparisons between maximum sodium and chloride concentrations.

Date	Sodium	Chloride	Ratio, Sodium to Chloride
September 17, 1973	97	152	1.93 : 3
November 21, 1973	254	401	1.90 : 3
February 12 & 13, 1974	Avg. 3970	Avg. 6060	1.98 : 3
May 8, 1974	13	20	1.95 : 3
Broadview groundwater	Avg. 304	Avg. 489	1.87 : 3

Upon viewing the results noted above one must bear in mind that only the November and February samples were directly associated with road salting. Apparently all the chlorides in the runoff are derived from salt, but the source of this material during the summer is hard to determine. Even the groundwater shows evidence of salt, and the conclusion must be made that the salt percolates into the ground during the winter and early spring.

(d) Lead - Lead in the environment has come to be associated with automobile emissions and several studies have been made in this regard [10] [15] [16] [17]. This study tended to confirm Bryan's [15] statement that lead in urban runoff is associated with suspended solids, and hence tends to settle out when flow velocities and carrying capacities decline; but there appeared to be no definite connection in this work between the lead in the particulate material and automobile emissions. The highest concentrations occurred in the February snowmelt samples, which showed the high chloride concentrations. This would indicate a relationship between winter maintenance and lead, but again the lead could have reached the melting snow by some route other than winter maintenance.

(e) Phenolic Compounds - The only fact of note here is the lack of phenolic compounds in the Broadview outfall compared to Barrington. While Barrington concentrations rose as high as 145 micrograms per litre, Broadview never got above 7. There is no apparent reason for this difference, although Broadview was only tested three times compared to 18 for Barrington. However, on the days when both outfalls were tested, Broadview results were always lower.

5.3 Flow Weighted Means

In Table 9 the flow weighted mean is indicated for each sampling period. In order that this value be calculated, a series of samples taken at constant intervals was necessary, and this precluded the use of the 1973 work at Broadview. Where "No Results" is shown, it indicates that samples were taken but were not useable for this calculation. The second last column indicates the actual mass of material conveyed to the Don River during the sampling period under consideration.

Of particular interest in these tables is the degree to which chlorides reflect winter salting. The chlorides table (Table 9K) illustrates the extreme concentrations and loadings found during the runoff period, and indicates that 1,140 kilograms of chloride reached the river during this 1-3/4 hour period. Presumably, then, about 1900 kilograms of salt reached the river in this time, assuming the chlorides amount to 35/58 of the mass of salt.

5.4 Microbiological Results

Microbiological samples taken in the early part of the study, from September, 1973 to early May, 1974, were single samples taken five minutes apart. Early in May the procedure was changed and from this point on the samples were taken in groups of three every 15 minutes.

It is quite possible that the values obtained from these samples from the beginning until January, 1975, were higher than those actually present in the storm water. This is based on the following:

(a) The procedure during this period involved a long period of time between sampling and delivery to the laboratory. When sampling started, the automatic sampler was turned on, and samples were not delivered to the laboratory until the next day when the bottles from the automatic sampler were retrieved and all samples delivered. The microbiological samples stayed in the cool of the sewer at about 10^{o} to 12^{o}C for several hours, then were taken home and refrigerated by the sampling personnel. Next day they were delivered to the laboratory, but this involved two to three hours in a station wagon. A sample taken at 9 a.m. could reach the laboratory at 11 a.m. next day, having spent only 14 of the intervening 26 hours under refrigeration.

(b) The test results for coliforms was higher on many occasions than results for Detroit [3] and Washington [8]. It could be only the writer's personal prejudice but he feels that the residential areas drained by the two East York outfalls must be cleaner than the American cities previously mentioned, with consequent lower coliform counts. However, the evidence of our test results does not entirely bear this out.

Shown in Table 10 are the minimum and maximum values obtained during this study. Metro Bylaw 2520 specifies only the maximum for coliforms and the limit is 2400 per 100 ml. During this study not one sample showed a count below this figure. There is no question that the fecal coliforms are derived from the animal and bird population of the area and not from sanitary sewage. A visit to the test sites will show

that there is virtually no flow between rainfalls and there is no sewage smell of any kind. A comparison with the values shown in Table 1 shows that many of our values are well in excess of those reported. The highest value is 3.2×10^6 coliforms, from Washington, and eight of the sampling programs in the present study exceeded this value.

5.5 Catch Basin Studies

As part of this study samples were taken from catch basin sumps located in various areas of the Borough for a period of eight or ten days after a rainfall. BOD well in excess of 100 mg/l was recorded several times and suspended solids were fairly substantial even though the sampling personnel was careful not to stir up the sediments in the catch basin. In the two drainage areas there are 193 catch basins each with about 280 litres of water. During a rainfall, particularly a gentle rainfall, most if not all of the water washed into the sewer at the beginning of the runoff would be this sump water, with the bottom sediments stirred up, and this would contribute to the high readings noted in the water in the sewer. Visual observation of water flowing in a street gutter showed that when it entered the catch basin it was fairly clean, but when sampled in the sewers, early samples were often black.

6 CONCLUSIONS AND RECOMMENDATIONS

The results of this study have already been compared to the Bylaw 2520 requirements and have been shown to exceed them in many cases. Bylaw 2520 has been interpreted in some quarters as applying only to drainage to storm sewers, and not to the flow from a municipal storm sewer. It would appear that, if the quality of the environment is the main consideration for the enactment of Bylaw 2520, then this bylaw should apply also to municipal storm drainage systems. The evidence in support of this is found in the Barrington area where most of the water reaching the storm sewer comes from road pavements and sidewalks. The concentrations and mass loadings from this outfall, even with only some 20 hectares draining to it, are significant enough to merit attention, and can only increase as the drainage area increases.

Bylaw 2520 itself refers only to concentrations, and these do not reflect sufficiently the true condition of the storm drainage. The mass loading, which indicates the actual mass of material reaching the watercourse, would be a more effective figure upon which to base legislation, but has obvious problems. Methods of determining concentrations are straightforward enough to present no problem, but an accurate flow measurement is extremely difficult to achieve, and use of the mass loading requires a flow measurement accurate enough to stand up in court. Some research into this field would provide some information on measuring flows of water in sewers and methods of overcoming the difficulties of presenting them in a court of law.

Recommendation No. 1

That legislation governing urban storm water runoff be revised, and not be based on concentration alone. Legislation should be based on a figure which takes into account both concentration and volume of flow.

The study of the quality of water in catch basin sumps shows that this water is of very poor quality. In addition, visual observations of water flowing in the sewer in the early part of a storm appear to indicate that much of this water is coming from these sumps. The obvious conclusion then would be that the elimination of these sumps would improve the runoff quality in the early stages of runoff events.

Sumps have been installed in catch basins for years, and appear to have their origins as collection points for sand from unpaved roads. Now that urban roads are usually paved with proper curbs, this reason is eliminated and the sumps are no longer required.

Recommendation No. 2

That local municipalities be urged to abandon the sumps which have traditionally formed part of a catch basin structure.

Going one step backwards in the process of runoff, all impurities in catch basin sumps, and in storm water reaching the sewers, come from the ground surface, particularly the road pavement. If this pavement were cleaned more thoroughly the runoff quality would not be as bad. Consequently, better municipal housekeeping would improve runoff quality.

Recommendation No. 3

That local municipalities be urged to upgrade the priorities given to the services which clean up the roads and streets in urban areas. This would apply particularly to street sweeping and catch basin cleaning, where catch basin sumps remain in existence.

This study did not confirm the existence of a "first flush" in storm water runoff to any great extent. However, any rise in concentration in the latter stages of a storm were not as high as the initial values. This is illustrated particularly in the suspended solids graphs. Highest concentration and mass loadings were found in the initial runoff, and this is the storm water which exceeds the Bylaw 2520 limits and should be treated.

Recommendation No. 4

That consideration be given to the storage and treatment of the initial runoff from a storm.

Storm sewer systems are used for more than just runoff from storms. The February, 1974, snowmelt samples were taken on a day when the sun was shining. Homeowners frequently wash their cars on driveways and streets and the soapy water flows to the catch basins. Some people having a liquid considered to be too foul for their plumbing fixtures

will pour it down a catch basin. These and many other similar uses result in a sizeable contribution to water pollution which is exclusive of any storm runoff. Luckily these are low-flow uses and could easily be accommodated in a treatment plant.

The largest flow of this type is likely to be runoff from melting snow. In February, 1974, the volume of runoff when samples were taken amounted to about 2-3% of the design flow from this area. Consequently, if 5% of all flow in the sewer were treated, all flows of this nonstorm runoff type would be accommodated.

Recommendation No. 5

That consideration be given to the storage and treatment of all flow in storm sewers below 5% of the design flow.

Road salt is deposited only on the road pavement and presumably concentrates in the windrows of snow piled by plows at the side of the road. In downtown areas and on main streets this snow is removed as a matter of course, to provide better pedestrian and vehicular movement. If the pollutants are concentrated in the snow, a significant reduction in loadings would be achieved by removing more snow. This would assume, of course, that the snow is moved to some spot where, when it melts, it does not flow directly into the rivers.

Recommendation No. 6

That research be conducted to confirm that pollutants concentrate in the windrows of snow beside a road pavement.

Recommendation No. 7

That local municipalities be urged to remove more snow from the streets and dump it in locations where it will not cause serious pollution problems when it melts.

Recommendation No. 8

That municipalities using snow melters to dispose of snow windrows be requested to ensure that the melted snow is directed to a combined or sanitary sewer and not to a storm sewer.

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APPENDIX A

TABLES AND GRAPHS

TABLE 6. COMPARISON BETWEEN BYLAW 2520 REQUIREMENTS AND MAXIMUM VALUES OF TEST RESULTS FOR VARIOUS STORMS

CHEMICAL PARAMETERS

		pH	Suspended Solids mg/l	BOD mg/l	Lead mg/l	Iron mg/l	Phenolic Compounds mg/l	Chlorides mg/l	Sulphates mg/l
METRO BY-LAW 2520		5.5 to 9.5	30	20	5	17	.04	1500	1500
BROADVIEW	September 17, 1973	7.1 to 7.6	600	90	1.10	-	-	152	146
	November 21, 1973	7.4 to 8.0	75	100	0.59	-	-	401	150
	July 29, 1974	-	80	19	0.46	-	.002	84	-
	November 5, 1974	-	90	14	-	-	.003	45	-
	November 20, 1974	-	400	38	-	-	.007	61	-
BARRINGTON	May 8, 1974	-	60	24	.67	-	.027	20	124
	May 16, 1974	-	120	30	.50	-	.0045	10	8
	June 10, 1974	-	400	260	1.70	-	.048	57	40
	June 13, 1974	-	100	85	.64	-	.054	27	26
	June 18, 1974	-	115	11	.64	-	.003	5	-
	July 29, 1974	-	630	160	-	-	.030	84	-
	September 12, 1974	-	100	280	.67	-	.049	26	-
	September 17, 1974	-	100	220	.45	-	.020	13	-
	September 25, 1974	-	170	320	.87	-	.100	31	-
	November 5, 1974	-	400	220	1.80	-	.145	64	-
	November 20, 1974	-	220	75	1.80	-	.004	66	-
	January 29, 1975	-	195	46	0.80	-	.012	255	-
	August 21, 1975	-	100	110	0.73	-	.042	125	44
	September 11, 1975	-	160	160	-	-	-	107	-
	October 1, 1975	-	195	65	0.89	-	.013	34	-
	November 7, 1975	-	100	85	0.59	-	.070	33	-
	December 30, 1975	-	340	45	1.60	-	.065	7075	-
	January 26, 1976	-	295	24	1.50	-	.075	5885	-
	February 18, 1976	-	175	7	1.00	-	.030	127	-

TABLE 6. (CONT.)

CHEMICAL PARAMETERS

	pH	Suspended Solids mg/l	BOD mg/l	Lead mg/l	Iron mg/l	Phenolic Compounds mg/l	Chlorides mg/l	Sulphates mg/l
SPECIAL SAMPLES								
Barrington Snowmelt								
February 12, 1974	-	1570	80	.32	-	-	14000	200
February 13, 1974	-	560	70	.21	-	-	5980	200
Broadview Snowmelt								
February 12, 1974	-	440	46	4.3	-	-	6140	240
February 13, 1974	-	410	36	2.5	-	-	4930	160
Broadview Groundwater	7.8	-	-	<0.12	-	-	488	160
November 28, 1973								
Barrington	-	-	-	-	3.0	-	-	-
Broadview	-	-	-	-	5.8	-	-	-

TABLE 7. MAXIMUM CONCENTRATIONS RECORDED FOR ALL OTHER CHEMICAL PARAMETERS STUDIED

		TOC mg/l	COD mg/l	Total Phosphorus mg/l	Dissolved Phosphorus mg/l	Ammonia mg/l	Total Kjeldahl mg/l	Nitrite mg/l	Nitrate mg/l	Sodium mg/l	Potassium mg/l	Hardness as Ca CO_3 mg/l	Alkalinity as CA CO_3 mg/l	Conductivity µmhos per cm	Dissolved Solids mg/l	Total Solids mg/l	Total Solids - Ashed mg/l	Total Solids - Loss mg/l
BROADVIEW	September 17,1973	-	430	1.50	.30	.50	7.5	1.9	1.6	97	18	588	154	1020	1100	1670	1420	300
	November 21,1973	-	180	.30	.06	.40	3.5	.16	4.9	254	9.5	376	219	1750	1170	1220	1055	165
	July 29,1974	40	120	.40	.04	.10	2.5	.14	2.1	-	-	-	-	590	-	-	-	-
	November 5,1974	38	120	.80	.06	.20	2.5	<.04	<.40	-	-	-	-	345	-	-	-	-
	November 20,1974	-	490	1.0	.02	.10	7.5	.12	.80	-	-	-	-	455	-	-	-	-
BARRINGTON	May 8,1974	-	120	.60	.10	.70	2.5	.30	1.5	13	2.5	88	68	265	230	290	-	-
	May 16,1974	-	120	.80	.90	.20	2.5	<.02	<.20	9	2.2	76	73	-	-	-	-	-
	June 10,1974	-	700	4.0	.90	.60	16	<.02	<.20	31	27	168	132	520	-	-	-	-
	June 13,1974	76	320	3.0	.64	.20	11	<.02	<.20	17	23	132	93	365	-	-	-	-
	June 18,1974	75	160	.60	.06	.20	3	.02	.40	-	-	-	-	106	-	-	-	-
	July 29,1974	220	740	2.7	.08	1.4	10	.26	1.9	-	-	-	-	635	-	-	-	-
	September 12,1974	-	790	1.2	.30	.10	8	.04	<.20	-	-	-	-	470	-	-	-	-
	September 17,1974	-	440	.72	.04	.10	4.4	<.02	<.20	-	-	-	-	220	-	-	-	-
	September 25,1974	158	810	1.6	.04	.10	10	.02	<.20	-	-	-	-	515	-	-	-	-
	November 5,1974	225	880	3.8	2.2	.40	8	<.04	<.40	-	-	-	-	520	-	-	-	-
	November 20,1974	-	40	.32	.06	.20	1.0	.04	.80	-	-	-	-	325	-	-	-	-
	January 29,1975	26	140	.80	.14	.20	6	.06	<.20	-	-	-	-	1015	-	-	-	-
	August 21,1975	-	-	2.0	.26	3.1	15	.24	1.0	-	-	-	-	885	-	-	-	-
	September 11,1975	-	-	11	1.2	5.2	20	.90	.26	-	-	-	-	1045	-	-	-	-
	October 1,1975	-	310	1.4	.40	.60	4.7	.66	1.0	-	-	-	-	310	225	265	-	-
	November 7,1975	-	310	1.7	.60	.10	6.5	.12	<.20	-	-	-	-	478	-	-	-	-
	December 30,1975	-	910	.56	.14	1.5	3.3	.42	1.6	-	-	-	-	20500	-	-	-	-
	January 26,1976	-	770	.49	.10	.90	10.0	.44	2.1	-	-	-	-	17000	-	-	-	-
	February 18,1976	-	175	.42	.18	.80	2.6	.14	1.5	-	-	-	-	610	-	-	-	-

TABLE 8. MAXIMUM MASS LOADINGS - CHEMICAL PARAMETERS

		BOD	Suspended Solids	Total Solids	Dissolved Solids	Total Solids - Ashed	Total Solids - Lost	Ammonia	Total Kjeldahl	Nitrite	Nitrate
		(kilograms per hour)									
BROADVIEW	September 17, 1973	16.79	93.9	255	168	217	56	.0678	1.109	.257	.259
	November 21, 1973	8.46	15.3	134.3	126.6	117.2	17.1	.0273	.535	.0231	.709
	July 29, 1974	2.01	9.45	-	-	-	-	.0118	.236	.0165	.248
	November 5, 1974	2.86	40.6	-	-	-	-	.0409	.339	-	-
	November 20, 1974	8.06	118.5	-	-	-	-	.00337	1.54	.0224	.1491
BARRINGTON	May 8, 1974	1.79	2.69	13.0	10.30	-	-	.0314	.084	.0135	.0236
	May 16, 1974	4.28	16.0	-	-	-	-	.0267	.334	-	-
	June 10, 1974	49.2	115.5	-	-	-	-	.1730	4.63	-	-
	June 13, 1974	21.1	24.4	-	-	-	-	.0354	1.47	-	-
	June 18, 1974	1.59	18.8	-	-	-	-	.0578	.867	.00578	.0535
	July 29, 1974	14.2	54.5	-	-	-	-	.124	.796	.0089	.240
	September 12, 1974	26.3	15.91	-	-	-	-	.0155	1.081	.0027	-
	September 17, 1974	29.4	12.0	-	-	-	-	.1335	.587	-	-
	September 25, 1974	28.9	15.5	-	-	-	-	.0089	.928	.00310	-
	November 5, 1974	13.5	24.2	-	-	-	-	.0135	.505	-	-
	November 20, 1974	1.01	3.37	-	-	-	-	.0135	.0673	.00179	.0359
	January 29, 1975	6.14	17.3	-	-	-	-	.0267	.668	.0080	-
	August 21, 1975	5.05	7.78	-	-	-	-	.139	1.01	.0294	.0885
	September 11, 1975	18.10	13.35	-	-	-	-	.206	1.12	.1391	.0402
	October 1, 1975	14.4	43.3	58.8	49.9	-	-	-	1.05	.146	.1068
	November 7, 1975	5.38	6.73	-	-	-	-	.0067	.262	.0027	-
	December 30, 1975	3.36	30.1	-	-	-	-	.098	.231	.0336	.107
	January 26, 1976	2.55	32.9	-	-	-	-	.010	1.11	.0489	.233
	February 18, 1976	0.80	24.0	-	-	-	-	0.80	.294	.0111	.174

TABLE 8 (CONT'D)

		Total Phosphorus	Dissolved Phosphorus	TOC	COD	Phenolic Compounds	Chlorides	Sodium	Potassium	Lead	Sulphate
		(kilograms per hour)				(Grams per hour)	(kilograms per hour)				
BROADVIEW	September 17, 1973	.239	.0406	-	80.2	-	20.6	13.14	2.44	.261	19.0
	November 21, 1973	.0459	.00409	-	19.4	-	39.8	24.8	1.451	.0903	21.7
	July 29, 1974	.0472	.00472	4.72	14.2	.236	9.45	-	-	.0569	-
	November 5, 1974	.1082	.00409	5.15	24.5	.612	2.86	-	-	-	-
	November 20, 1974	.238	.00067	-	66.4	1.421	5.10	-	-	.380	-
BARRINGTON	May 8, 1974	.0224	.0045	-	5.40	1.21	0.80	.58	.112	.0226	5.6
	May 16, 1974	.1068	.120	-	16.0	.600	.935	.80	.294	.0508	.935
	June 10, 1974	1.155	.1964	-	202	13.87	15.46	8.96	6.36	.492	8.67
	June 13, 1974	.488	.1032	16.8	70.9	12.0	5.55	3.55	4.07	.1264	6.21
	June 18, 1974	.1445	.0173	9.24	17.3	.578	1.445	-	-	.1184	-
	July 29, 1974	.240	.00708	20.0	71.2	2.66	7.35	-	-	-	-
	September 12, 1974	.1325	.0135	-	66.5	3.54	2.31	-	-	.082	-
	September 17, 1974	.0961	.00535	-	58.7	2.67	1.60	-	-	.060	-
	September 25, 1974	.1550	.0027	10.68	74.5	6.73	3.01	-	-	.0866	-
	November 5, 1974	.202	.113	13.8	50.5	8.10	2.62	-	-	.142	-
	November 20, 1974	.0188	.0027	-	2.69	.269	3.03	-	-	.0123	-
	January 29, 1975	.0935	.0160	3.47	18.7	1.87	31.5	-	-	.0548	-
	August 21, 1975	.0347	.135	-	-	2.92	5.65	-	-	.0467	3.74
	September 11, 1975	0.62	.068	-	-	-	4.16	-	-	-	-
	October 1, 1975	.244	.0843	-	68.7	2.88	7.54	-	-	.197	-
	November 7, 1975	.115	.0404	-	18.5	4.71	2.21	-	-	.035	-
	December 30, 1975	.0354	.0089	-	76.8	5.75	627	-	-	.142	-
	January 26, 1976	.0545	.0111	-	85.7	8.35	654	-	-	.167	-
	February 18, 1976	.0535	.0123	-	22.0	3.74	10.7	-	-	.134	-

TABLE 9A. FLOW WEIGHTED MEAN BOD

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.59	2.2313	14.3707
November 5, 1974	12	1.83	0.167	221.06	2.1950	9.949
November 20, 1974	11	1.67	0.167	297.71	6.8317	22.993
BARRINGTON						
May 8, 1974	24	1.92	0.083	63.99	1.6363	25.470
May 16, 1974	12	1.83	0.167	223.23	5.4067	24.269
June 10, 1974	5	2.0	0.50	311.76	53.1500	170.484
June 13, 1974	11	1.67	0.167	311.66	13.8083	44.394
June 18, 1974	5	2.0	0.50	511.56	2.3333	4.562
July 29, 1974	24	1.92	0.083	190.96	15.9550	83.216
September 12, 1974	12	1.83	0.167	196.71	29.7950	151.768
September 17, 1974	12	1.83	0.167	237.77	36.8433	155.261
September 25, 1974	12	1.83	0.167	200.68	35.9533	179.515
November 5, 1974	12	1.83	0.167	80.44	15.1033	188.133
November 20, 1974	11	1.67	0.167	93.61	0.8650	9.259
January 29, 1975	4	1.50	0.50	199.62	6.3500	31.810
August 21, 1975	8	1.75	0.25	161.55	8.5575	52.971
September 11, 1975	10	4.50	0.50	275.40	10.6700	38.744
October 1, 1975	8	1.75	0.25	200.48	8.9525	44.656
November 7, 1975	8	1.75	0.25	106.61	5.8975	55.321
December 30, 1975	8	1.75	0.25	111.83	4.6075	41.203
January 26, 1976	8	1.75	0.25	249.48	4.7725	19.130
February 18, 1976	8	1.75	0.25	161.87	1.0543	6.513

TABLE 9B. FLOW WEIGHTED MEAN

SUSPENDED SOLIDS

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/1)
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.59	7.8867	50.790
November 5, 1974	12	1.83	0.167	221.06	23.2050	105.181
November 20, 1974	11	1.67	0.167	297.71	69.0583	232.426
BARRINGTON						
May 8, 1974	24	1.92	0.083	63.99	3.3817	52.637
May 16, 1974	12	1.83	0.167	223.23	17.6117	79.054
June 10, 1974	5	2.0	0.50	311.91	78.8900	253.047
June 13, 1974	11	1.67	0.167	311.66	29.0750	93.487
June 18, 1974	5	2.0	0.50	511.56	25.6300	50.102
July 29, 1974	24	1.92	0.083	190.96	47.7417	249.005
September 12, 1974	12	1.83	0.167	196.71	14.8967	75.880
September 17, 1974	12	1.83	0.167	237.77	17.9500	75.643
September 25, 1974	12	1.83	0.167	200.68	20.6767	103.239
November 5, 1974	12	1.83	0.167	80.44	25.2667	314.732
November 20, 1974	11	1.67	0.167	93.61	3.8867	41.604
January 29, 1975	4	1.50	0.50	199.62	20.8450	104.423
August 21, 1975	8	1.75	0.25	161.55	11.0100	68.152
September 11, 1975	5	2.0	0.50	173.34	16.5800	95.650
October 1, 1975	8	1.75	0.25	200.48	26.6725	133.046
November 7, 1975	8	1.75	0.25	106.61	7.7675	72.862
December 30, 1975	8	1.75	0.25	111.83	32.3500	289.291
January 26, 1976	8	1.75	0.25	249.48	40.3500	161.736
February 18, 1976	7	1.50	0.25	145.04	25.5500	176.164

TABLE 9C. FLOW WEIGHTED MEAN COD

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.59	15.435	99.616
November 5, 1974	12	1.83	0.167	221.06	16.947	72.814
November 20, 1974	11	1.67	0.167	297.71	58.267	195.937
BARRINGTON						
May 8, 1974	24	1.92	0.083	63.99	6.177	96.155
May 16, 1974	12	1.83	0.167	223.23	18.918	84.194
June 10, 1974	5	2.0	0.50	311.76	56.300	541.763
June 13, 1974	11	1.67	0.167	311.66	55.900	179.720
June 18, 1974	5	2.0	0.50	511.56	22.975	44.912
July 29, 1974	24	1.92	0.083	190.96	70.417	367.270
September 12, 1974	12	1.83	0.167	196.71	77.717	395.867
September 17, 1974	12	1.83	0.167	237.77	81.933	345.273
September 25, 1974	12	1.83	0.167	200.68	103.200	515.279
November 5, 1974	12	1.83	0.167	80.44	56.217	700.257
November 20, 1974	11	1.67	0.167	93.61	2.808	30.061
January 29, 1975	8	1.75	0.25	199.98	21.015	105.086
October 1, 1975	8	1.75	0.25	200.48	46.588	232.386
November 7, 1975	8	1.75	0.25	106.61	26.750	250.926
December 30, 1975	8	1.75	0.25	111.83	77.475	692.824
January 26, 1976	8	1.75	0.25	249.48	130.250	522.086
February 18, 1976	8	1.75	0.25	161.87	25.725	158.929

TABLE 9D. FLOW WEIGHTED MEAN

TOC - SODIUM & POTASSIUM

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
TOC						
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.59	5.0817	32.726
November 5, 1974	12	1.83	0.167	221.06	4.1617	18.864
BARRINGTON						
June 13, 1974	11	1.67	0.167	311.66	14.3350	46.087
June 18, 1974	5	2.0	0.50	511.56	3.2550	19.089
July 29, 1974	24	1.92	0.083	190.96	46.9817	122.520
September 25, 1974	12	1.83	0.167	200.68	16.3950	81.860
November 5, 1974	12	1.83	0.167	80.44	14.9200	185.850
January 29, 1975	4	1.50	0.50	199.62	3.9950	20.013
SODIUM						
May 8, 1974	6	2.5	0.50	111.91	1.3400	11.974
May 16, 1974	12	1.83	0.167	219.50	1.2583	5.744
June 10, 1974	24	1.92	0.083	158.69	3.4467	21.632
June 13, 1974	12	1.83	0.167	318.99	4.0067	12.585
POTASSIUM						
May 8, 1974	6	2.5	0.50	111.91	0.2465	2.203
May 16, 1974	12	1.83	0.167	219.50	0.4618	2.108
June 10, 1974	24	1.92	0.083	158.69	3.3833	21.235
June 13, 1975	12	1.83	0.167	318.99	3.7745	11.857

TABLE 9E. FLOW WEIGHTED MEAN

FREE AMMONIA

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
BROADVIEW						
July 29, 1974	No Results					
November 5, 1974	11	1.67	0.167	201.28	0.0402	0.199
November 20, 1974	No Results					
BARRINGTON						
May 8, 1974	6	2.50	0.50	111.96	0.0543	0.485
May 17, 1974	No Results					
June 10, 1974	No Results					
June 13, 1974	No Results					
June 18, 1974	12	0.92	0.083	288.28	0.0314	0.109
July 29, 1974	5	2.0	0.50	243.54	0.1532	0.629
September 12, 1974	No Results					
September 17, 1974	12	1.83	0.167	241.50	0.2409	0.999
September 25, 1974	No Results					
November 5, 1974	12	1.83	0.167	84.20	0.0176	0.210
November 20, 1974	No Results					
January 29, 1975	No Results					
August 21, 1975	8	1.75	0.25	161.55	0.1701	1.053
September 11, 1975	No Results					
October 1, 1975	No Results					
November 7, 1975	No Results					
December 30, 1975	8	1.75	0.25	111.83	0.1468	1.312
January 26, 1976	8	1.75	0.25	249.48	0.0183	0.074
February 18, 1976	8	1.75	0.25	161.87	0.0893	0.552

TABLE 9F. FLOW WEIGHTED MEAN

TOTAL KJELDAHL

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.59	0.3003	1.934
November 5, 1974	11	1.67	0.167	201.28	0.2607	1.298
November 20, 1974	11	1.67	0.167	292.42	1.0422	3.571
BARRINGTON						
May 8, 1974	5	2.0	0.50	89.46	0.1850	2.068
May 16, 1974	12	1.83	0.167	219.50	0.3387	1.551
June 10, 1974	24	1.92	0.083	158.69	1.7348	10.888
June 13, 1974	12	1.83	0.167	319.00	1.6357	5.138
June 18, 1974	24	1.92	0.083	450.53	0.7860	1.738
July 29, 1974	5	2.0	0.50	243.54	1.5185	6.235
September 12, 1974	12	1.83	0.167	208.20	1.1422	5.497
September 17, 1974	12	1.83	0.167	241.50	0.8652	3.590
September 25, 1974	12	1.83	0.167	193.17	1.3198	6.846
November 5, 1974	12	1.83	0.167	84.20	0.5048	6.008
November 20, 1974	11	1.67	0.167	93.61	0.0770	0.824
January 29, 1975	8	1.75	0.25	199.98	0.8333	4.167
August 21, 1975	8	1.75	0.25	161.55	0.9269	5.737
September 11, 1975	8	1.75	0.25	158.72	1.3190	8.311
October 1, 1975	8	1.75	0.25	200.03	0.5383	2.691
November 7, 1975	8	1.75	0.25	106.61	0.2270	2.129
December 30, 1975	8	1.75	0.25	111.83	0.2860	2.558
January 26, 1976	8	1.75	0.25	249.48	1.6398	6.573
February 18, 1976	8	1.75	0.25	161.87	0.3603	2.226

TABLE 9G. FLOW WEIGHTED MEAN

NITRITE

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/1)
BROADVIEW						
July 29, 1974	11	1.67	0.167	322.60	0.0139	0.090
November 5, 1974	No Results					
November 20, 1974	11	1.67	0.167	292.42	0.0248	0.085
BARRINGTON						
May 8, 1974	6	2.50	0.50	111.96	0.0216	0.193
May 16, 1974	No Results					
June 10, 1974	No Results					
June 13, 1974	No Results					
June 18, 1974	19	1.50	0.083	402.57	0.0081	0.020
July 29, 1974	4	1.50	0.50	199.62	0.0076	0.038
September 12, 1974	8	1.167	0.167	97.03	0.0026	0.027
September 17, 1974	No Results					
September 25, 1974	9	1.33	0.167	149.33	0.0031	0.021
November 5, 1974	No Results					
November 20, 1974	No Results					
January 29, 1975	8	1.75	0.25	199.98	0.0095	0.047
August 21, 1975	No Results					
September 11, 1975	No Results					
October 1, 1975	8	1.75	0.25	200.03	0.0701	0.351
November 7, 1975	No Results					
December 30, 1975	8	1.75	0.25	111.83	0.0440	0.393
January 26, 1976	No Results					
February 18, 1976	8	1.75	0.25	161.87	0.0163	0.101

TABLE 9H. FLOW WEIGHTED MEAN

NITRATE

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.60	0.2432	1.566
November 5, 1974	No Results					
November 20, 1974	No Results					
BARRINGTON						
May 8, 1974	3	1.00	0.50	50.91	0.0217	0.425
May 16, 1974	No Results					
June 10, 1974	No Results					
June 13, 1974	No Results					
June 18, 1974	No Results					
July 29, 1974	No Results					
September 12, 1974	No Results					
September 17, 1974	No Results					
September 25, 1974	No Results					
November 5, 1974	No Results					
November 20, 1974	No Results					
January 29, 1975	No Results					
August 21, 1975	No Results					
September 11, 1975	No Results					
October 1, 1975	7	1.50	0.25	144.50	0.0938	0.649
November 7, 1975	No Results					
December 30, 1975	8	1.75	0.25	111.83	0.1450	1.297
January 26, 1976	No Results					
February 18, 1976	8	1.75	0.25	161.87	0.2165	1.338

TABLE 9I. FLOW WEIGHTED MEAN

TOTAL PHOSPHORUS

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.59	0.0431	0.278
November 5, 1974	11	1.67	0.167	201.28	0.0712	0.354
November 20, 1974	11	1.67	0.167	292.42	0.1689	0.579
BARRINGTON						
May 8, 1974	5	2.0	0.50	89.46	0.0438	0.489
May 16, 1974	12	1.83	0.167	219.50	0.0895	0.409
June 10, 1974	24	1.92	0.083	158.69	0.4590	2.881
June 13, 1974	12	1.83	0.167	319.00	0.5590	1.756
June 18, 1974	24	1.92	0.083	450.53	0.1692	0.374
July 29, 1974	5	2.0	0.50	243.54	0.3429	1.408
September 12, 1974	12	1.83	0.167	208.20	0.1709	0.823
September 17, 1974	12	1.83	0.167	241.50	0.1457	0.605
September 25, 1974	12	1.83	0.167	193.17	0.1966	1.020
November 5, 1974	12	1.83	0.167	84.20	0.2293	2.730
November 20, 1974	11	1.67	0.167	93.61	0.0216	0.232
January 28, 1975	8	1.75	0.25	199.98	0.1155	0.578
August 21, 1975	8	1.75	0.25	161.55	0.0319	0.197
September 11, 1975	8	1.75	0.25	158.72	0.3068	1.933
October 1, 1975	8	1.75	0.25	200.03	0.1704	0.852
November 7, 1975	8	1.75	0.25	106.61	0.1056	0.991
December 30, 1975	8	1.75	0.25	111.83	0.0464	0.415
January 26, 1976	8	1.75	0.25	249.48	0.0829	0.332
February 18, 1976	8	1.75	0.25	161.87	0.0588	0.364

TABLE 9J. FLOW WEIGHTED MEAN

SOLUBLE PHOSPHORUS

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.59	0.00349	0.0225
November 5, 1974	No Results					
November 20, 1974	No Results					
BARRINGTON						
May 8, 1974	6	2.5	0.50	111.91	0.00853	0.0763
May 16, 1974	No Results					
June 10, 1974	24	1.92	0.083	158.69	0.09917	0.6226
June 13, 1974	12	1.83	0.167	319.00	0.07224	0.2269
June 18, 1974	24	1.92	0.083	450.53	0.01686	0.0375
July 29, 1974	5	2.0	0.50	243.54	0.01043	0.0429
September 12, 1974	11	1.67	0.167	174.83	0.01657	0.0945
September 17, 1974	12	1.83	0.167	241.50	0.00697	0.0289
September 25, 1974	No Results					
November 5, 1974	12	1.83	0.167	84.20	0.11570	1.3769
November 20, 1974	No Results					
January 29, 1975	8	1.75	0.25	199.98	0.01491	0.0745
August 21, 1975	8	1.75	0.25	161.55	0.16085	0.9957
September 11, 1975	8	1.75	0.25	158.72	0.03667	0.2310
October 1, 1975	8	1.75	0.25	200.03	0.07500	0.3750
November 7, 1975	8	1.75	0.25	106.61	0.02265	0.2125
December 30, 1975	8	1.75	0.25	111.83	0.01107	0.0990
January 26, 1976	No Results					
February 18, 1976	8	1.75	0.25	161.87	0.01560	0.0964

TABLE 9K. FLOW WEIGHTED MEAN

CHLORIDES

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.59	11.03	71.02
November 5, 1974	11	1.67	0.167	201.28	3.97	19.75
November 20, 1974	11	1.67	0.167	292.42	5.80	19.86
BARRINGTON						
May 8, 1974	5	2.0	0.50	89.46	1.67	18.64
May 16, 1974	12	1.83	0.167	219.50	1.66	7.59
June 10, 1974	24	1.92	0.083	158.69	5.04	31.62
June 13, 1974	12	1.83	0.167	317.00	5.96	18.73
June 18, 1974	24	1.92	0.083	450.53	2.03	4.49
July 29, 1974	5	2.0	0.50	243.54	14.67	60.22
September 12, 1974	12	1.83	0.167	208.20	3.36	16.15
September 17, 1974	12	1.83	0.167	241.50	2.51	10.43
September 25, 1974	12	1.83	0.167	193.17	4.36	22.59
November 5, 1974	12	1.83	0.167	84.20	3.26	38.76
November 20, 1974	11	1.67	0.167	93.61	3.09	33.02
January 29, 1975	8	1.75	0.25	199.98	44.40	222.02
August 21, 1975	8	1.75	0.25	161.55	8.89	55.04
September 11, 1975	10	4.50	0.50	275.40	8.56	31.09
October 1, 1975	8	1.75	0.25	200.03	9.98	24.93
November 7, 1975	8	1.75	0.25	106.61	4.09	19.18
December 30, 1975	8	1.75	0.25	111.83	654.50	5,855.13
January 26, 1976	8	1.75	0.25	249.48	1,140.00	4,569.50
February 18, 1976	8	1.75	0.25	161.87	14.38	88.84

TABLE 9L. FLOW WEIGHTED MEAN

LEAD

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.59	0.0489	0.315
November 5, 1974	12	1.83	0.167	221.06	0.0740	0.335
November 20, 1974	11	1.67	0.167	297.71	0.2501	0.845
BARRINGTON						
May 8, 1974	6	2.50	0.50	111.91	0.0502	0.448
May 16, 1974	12	1.83	0.167	219.50	0.0668	0.305
June 10, 1974	5	2.0	0.50	311.76	0.3611	1.158
June 13, 1974	11	1.67	0.167	311.66	0.1734	0.557
June 18, 1974	5	2.0	0.50	511.56	0.1543	0.302
September 12, 1974	5	2.0	0.50	288.90	0.1485	0.514
September 17, 1974	5	2.0	0.50	311.58	0.0906	0.291
September 25, 1974	12	1.83	0.167	200.68	0.0939	0.469
November 5, 1974	12	1.83	0.167	80.44	0.1117	1.391
November 20, 1974	11	1.67	0.167	93.61	0.0163	0.175
January 29, 1975	3	1.0	0.50	155.34	0.0752	0.484
August 21, 1975	8	1.75	0.25	161.55	0.0741	0.458
October 1, 1975	8	1.75	0.25	200.48	0.1226	0.611
November 7, 1975	7	1.50	0.25	100.94	0.0492	0.487
December 30, 1975	8	1.75	0.25	111.83	0.1563	1.397
January 26, 1976	8	1.75	0.25	249.48	0.2302	0.923
February 18, 1976	8	1.75	0.25	161.87	0.1517	0.937

TABLE 9M. FLOW WEIGHTED MEAN

PHENOLIC COMPOUNDS

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (grams)	Flow Weighted Mean (mg/1)
BROADVIEW						
July 29, 1974	11	1.67	0.167	155.59	0.310	0.00199
November 5, 1974	12	1.83	0.167	221.06	0.352	0.00159
November 20, 1974	11	1.67	0.167	297.71	1.701	0.00573
BARRINGTON						
May 8, 1974	24	1.92	0.083	63.99	0.573	0.00892
May 16, 1974	12	1.83	0.167	223.23	0.699	0.00314
June 10, 1974	5	2.0	0.50	311.76	12.060	0.03870
June 13, 1974	11	1.67	0.167	311.66	7.503	0.02412
June 18, 1974	5	2.0	0.50	511.56	0.567	0.00110
July 29, 1974	24	1.92	0.083	190.96	2.634	0.01374
September 12, 1974	12	1.83	0.167	196.71	5.287	0.02693
September 17, 1974	12	1.83	0.167	237.77	3.051	0.01286
September 25, 1974	12	1.83	0.167	200.68	8.382	0.04185
November 5, 1974	12	1.83	0.167	80.44	8.740	0.10887
November 20, 1974	11	1.67	0.167	93.61	0.366	0.00392
January 29, 1975	4	1.50	0.50	199.62	2.178	0.01091
August 21, 1975	8	1.75	0.25	161.55	3.900	0.02414
October 1, 1975	8	1.75	0.25	200.48	1.700	0.00848
November 7, 1975	8	1.75	0.25	106.61	1.839	0.01726
December 30, 1975	8	1.75	0.25	111.83	6.258	0.05596
January 26, 1976	8	1.75	0.25	249.48	13.760	0.05515
February 18, 1976	8	1.75	0.25	161.87	2.820	0.02613

TABLE 9N. FLOW WEIGHTED MEAN

SULPHATES

Storm	No. Samples	Duration (hours)	Time Between Samples (hours)	Total Flow Volume (m^3)	Total Mass (kg)	Flow Weighted Mean (mg/l)
BARRINGTON						
May 8, 1974	6	2.50	0.50	111.91	4.327	38.67
May 16, 1974	12	1.83	0.167	219.50	1.496	6.83
June 10, 1974	24	1.92	0.083	158.69	5.267	32.68
June 13, 1974	12	1.83	0.167	319.00	6.365	19.99
August 21, 1975	8	1.75	0.25	161.55	5.488	33.97

TABLE 10. MICROBIOLOGICAL RESULTS

	Date	Fecal Coliforms	Enterococcus	Background Colonies	Coliform Bacteria	
		All figures are (Bacterial Count per 100 ml) $\times 10^6$				
BROADVIEW	September 17, 1973	0.005 - 0.015	0.0031 - 0.0062	-	0.11 - 0.75	a
	November 21, 1973	0.001 - 0.42	0.0049 - 0.034	-	0.01 - 1.76	a
	November 5, 1974	0.0013 - 0.008	<0.015 - 0.033	.303 - 1.4	0.057 - 0.11	b
	November 20, 1974	0.0057 - 1.1	0.0043 - 0.063	.077 - 4.3	0.037 - 4.7	b
BARRINGTON	May 8, 1974	0.0021 - 0.15	0.0072 - 0.0224	<1.5 - 3.8	0.09 - 1.82	a
	June 10, 1974	0.30 - 1.16	>0.15 - 10^6	>0.15 - 10^6	>1.5 - 10^6	b
	June 13, 1974	0.26 - 2.4	0.053 - 0.310	73 - 387	43 - 193	b
	June 18, 1974	0.076 - 0.11	0.0106 - 0.050	1.05 - 2.9	.193 - .83	b
	July 29, 1974	0.03 - 0.19	0.160 - 0.430	8.5 - 30	3.5 - 16.9	b
	September 12, 1974	0.05 - 0.49	0.061 ->0.15	12 - 75	8.9 - 17	b
	September 17, 1974	0.06 ->0.15	0.107 - 0.383	4.3 ->15	1.3 ->15	b
	September 25, 1974	<.01 - 0.28	<0.010 - 1.55	<15 - 30	1.8 - 20.3	b
	November 5, 1974	0.05 - 0.33	0.147 - 1.4	21 - 55	2.3 - 7.6	b
	November 20, 1974	<.01 - 0.08	0.130 - 0.140	<.1 - .37	<.1 - .1	b
	August 21, 1975	0.004 - 0.31	0.042 - 0.183	3.1 - 7.1	.07 - 1.57	b
	September 11, 1975	0.02 - 1.4	0.030 - 0.330	13 - 110	.46 - 6.6	b

a - results of 1 sample

b - average of 3 samples

EXPLANATION OF THE GRAPHS

The following graphs contain all known information relevant to the parameter in question for a 17-hour period starting five hours prior to the start of manual sampling and continuing to the end of the automatic sampling program, 12 hours after start of sampling. Where available, the rainfall is indicated along the top bar of the graph, and the reader can determine from this information the position of the sampling program relative to the start and end of rainfall. The rainfall rate is given in ten-minute increments since this was the time span intervals on the rainfall recorder's graph paper.

The flow, concentration, and mass loading curves all start at time 0 hours and generally end after 1 hour 45 minutes or 2 hours. The concentration curve may continue past this point when tests were performed on the automatic sampler bottles, but since flow data was obtained only once beyond the manual sampling period no mass loading was determined.

Tests were run on all samples in all 20 sampling events for the four nitrogen and two phosphorus forms. However, graphs are only included where a reasonable number of samples tested above the lower detection limit of the equipment used for the tests. This limit is as follows for the various parameters.

Dissolved Phosphorus	-	0.02 mg/l
Ammonia	-	0.10 mg/l
Nitrite	-	0.02 mg/l, but occasionally 0.04 mg/l
Nitrate	-	0.20 mg/l, but occasionally 0.10 and 0.40 mg/l

Where there were less than 20 graphs for the other parameters, tests were not made on the samples for the missing events.

Only the storm of September 11, 1975 is presented herein. The remaining data is on file with the Ontario Ministry of the Environment and may be obtained on a loan basis from Mr. D.G. Weatherbe, Water Resources Branch, Ontario Ministry of the Environment, Toronto, Ontario M4V 1P5.

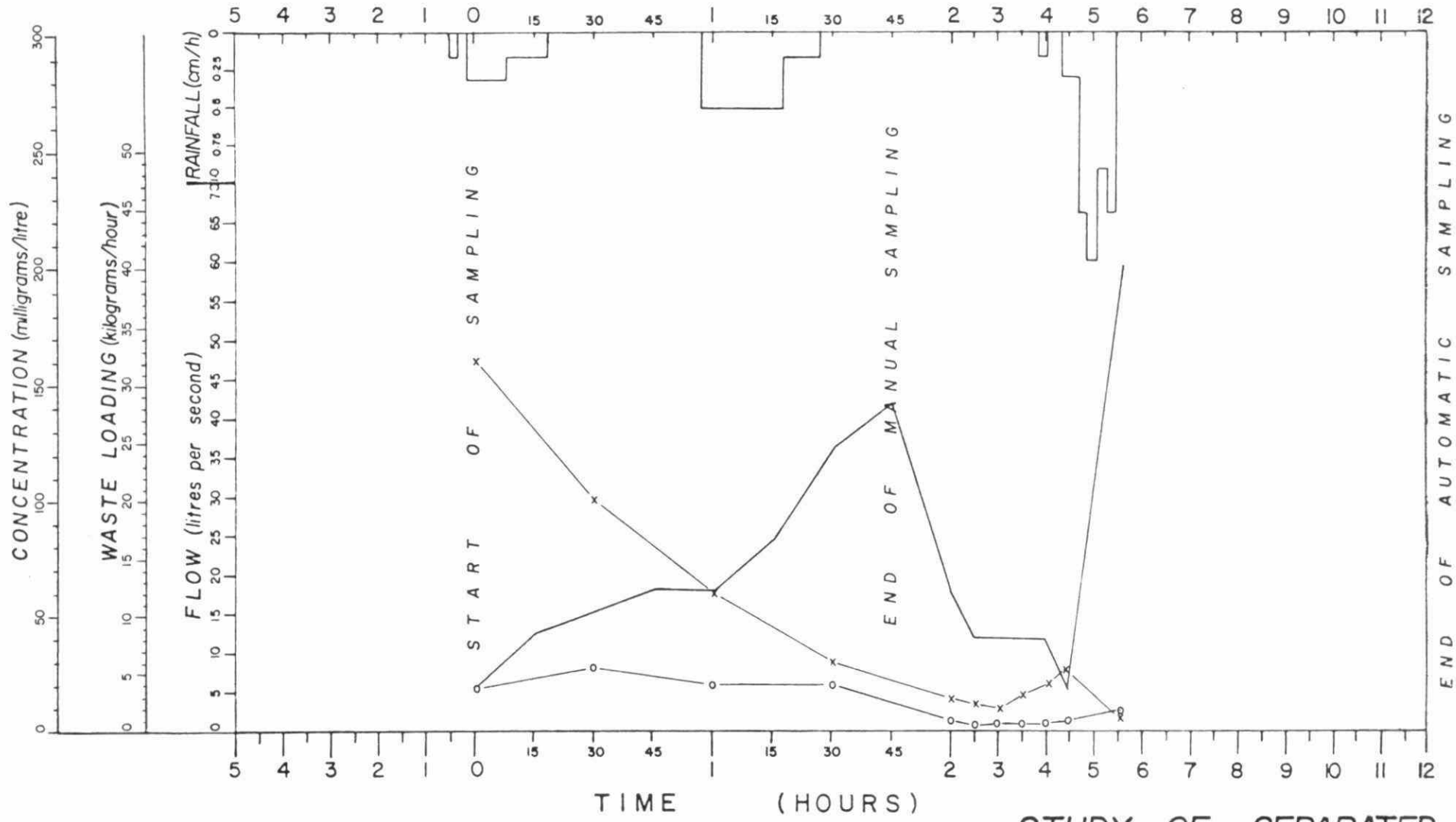

FIGURE: 19

PARAMETER: B.O.D.

LOCATION: BARRINGTON

DATE: SEPT. 11, 1975

TIME OF START OF SAMPLING : 3·45 P.M.

LEGEND:

CONCENTRATION —— x —— x ——

WASTE LOADING —— o —— o ——

FLOW ——————

STUDY OF SEPARATED STORM SEWER RUNOFF FROM URBAN AREAS- BOROUGH OF EAST YORK.

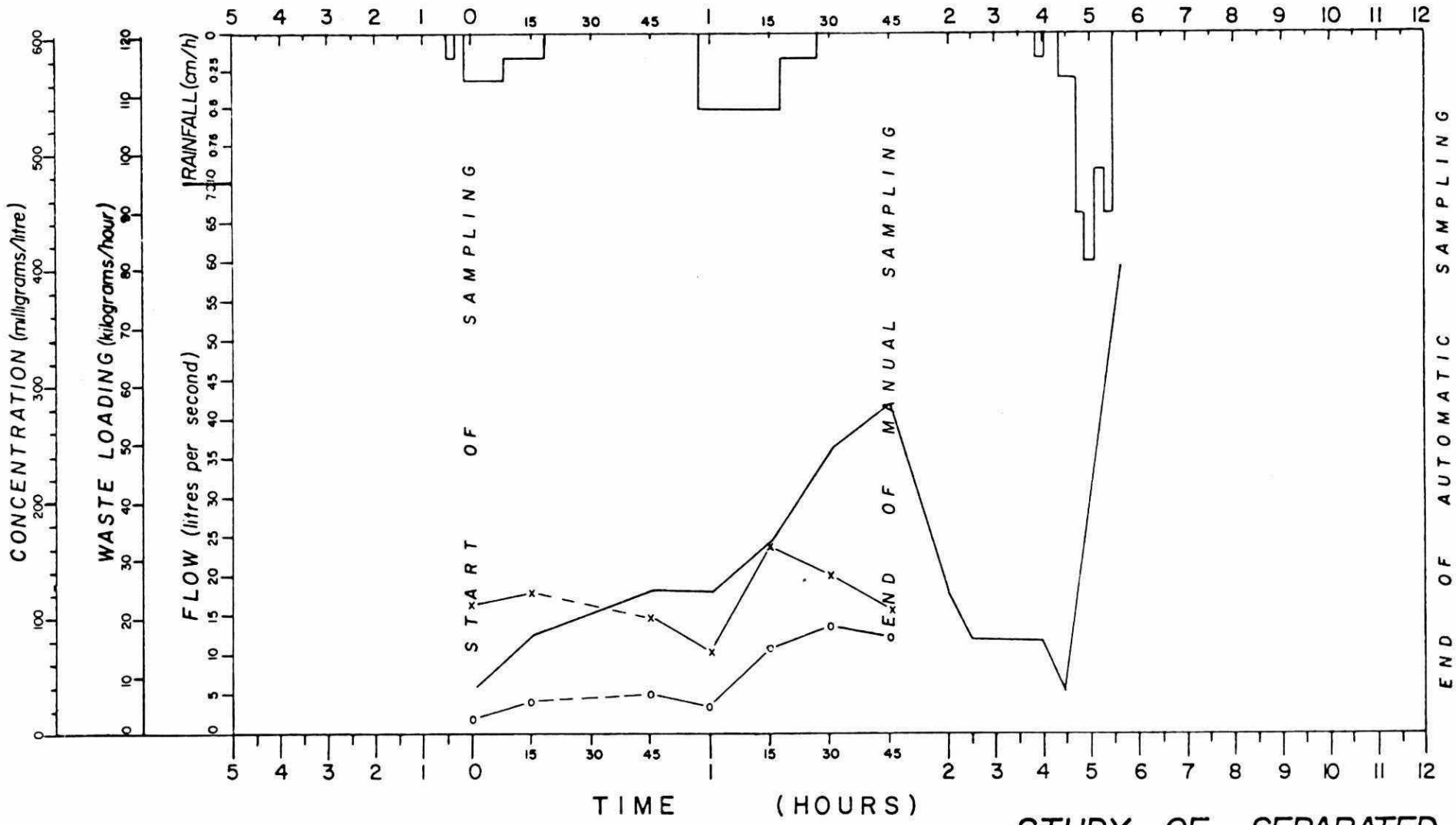

FIGURE: 39

PARAMETER: Suspended Solids

LOCATION: *BARRINGTON*

DATE: *SEPT. 11, 1975*

TIME OF START OF SAMPLING : *3:45 P.M.*

LEGEND:

CONCENTRATION — x — x —

WASTE LOADING — o — o —

FLOW ———

STUDY OF SEPARATED STORM SEWER RUNOFF FROM URBAN AREAS- BOROUGH OF EAST YORK.

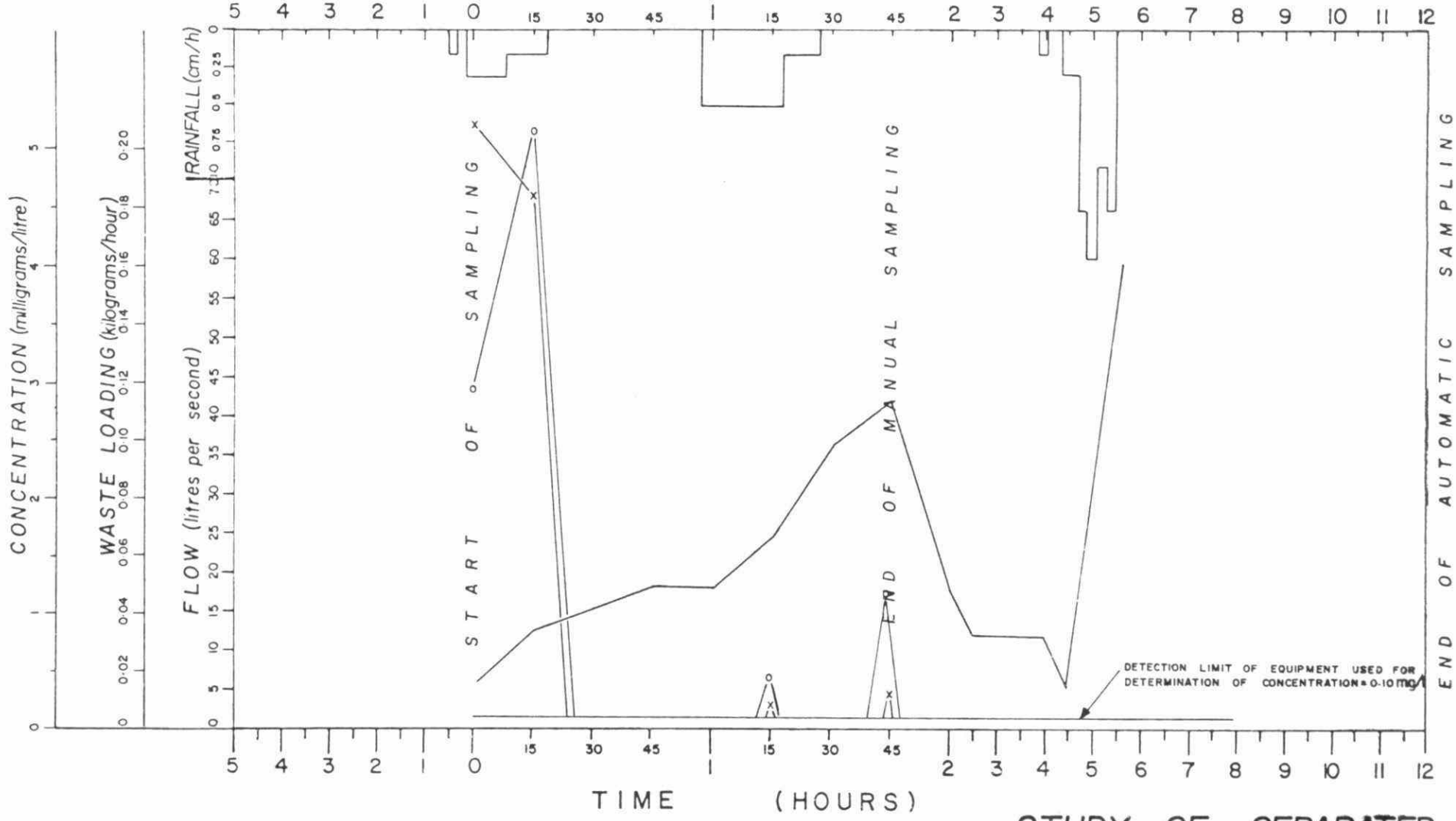
CONCENTRATION (milligrams/litre)
WASTE LOADING (kilograms/hour)
FLOW (litres per second)
RAINFALL (cm/h)
START OF SAMPLING
END OF MANUAL SAMPLING
END OF AUTOMATIC SAMPLING
DETECTION LIMIT OF EQUIPMENT USED FOR DETERMINATION OF CONCENTRATION = 0·10 mg/l
TIME (HOURS)

FIGURE: 83

PARAMETER: Free Ammonia

LOCATION: BARRINGTON

DATE: SEPT. 11, 1975

TIME OF START OF SAMPLING : 3·45 P.M.

LEGEND:

CONCENTRATION — x — x —

WASTE LOADING — o — o —

FLOW ———

STUDY OF SEPARATED STORM SEWER RUNOFF FROM URBAN AREAS - BOROUGH OF EAST YORK.

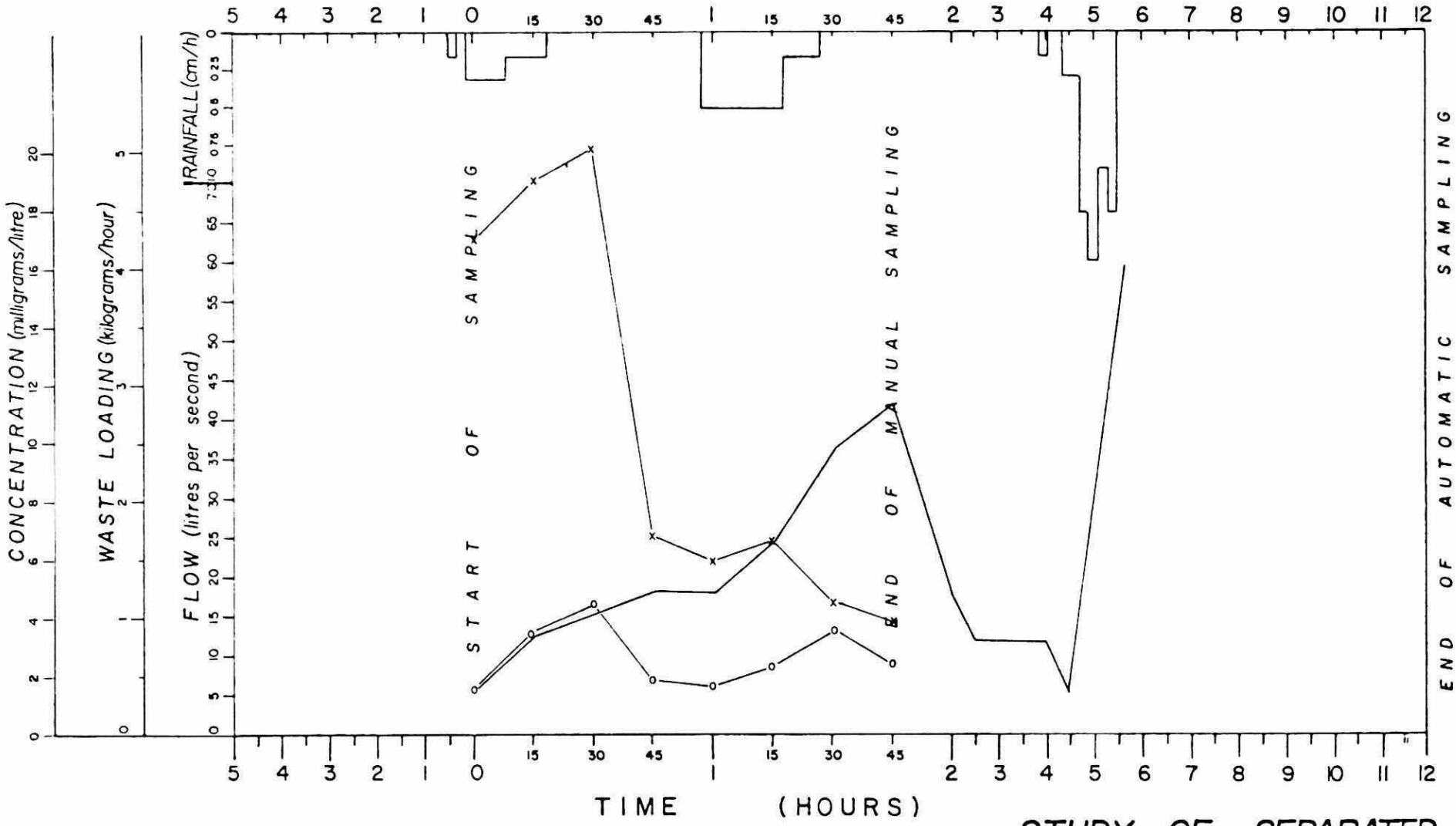

FIGURE: 102

PARAMETER: Total KJELDAHL

LOCATION: BARRINGTON

DATE: SEPT. 11, 1975

TIME OF START OF SAMPLING : 3·45 P.M.

LEGEND:

CONCENTRATION — x — x —

WASTE LOADING — o — o —

FLOW ———

STUDY OF SEPARATED STORM SEWER RUNOFF FROM URBAN AREAS - BOROUGH OF EAST YORK.

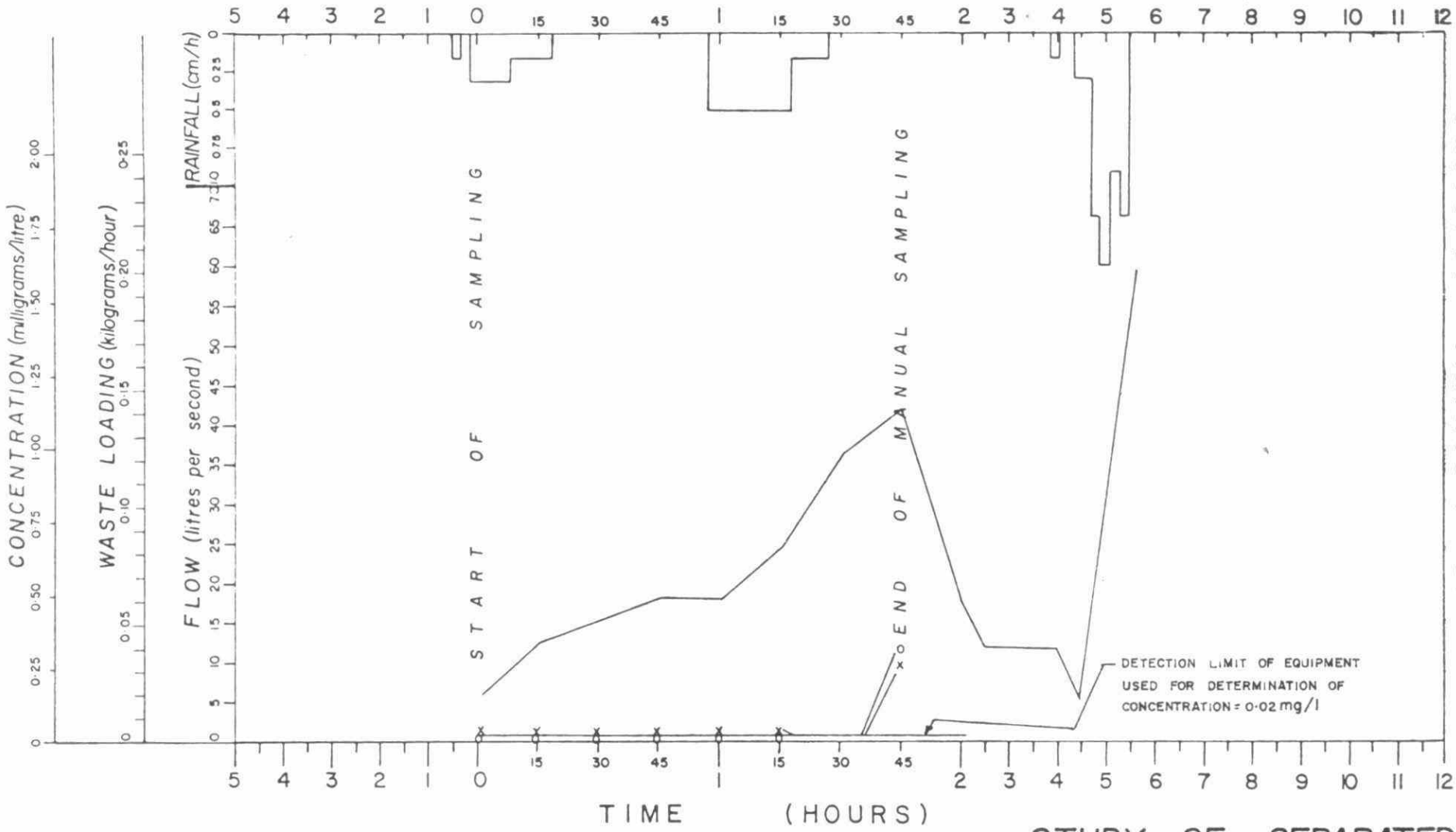
CONCENTRATION (milligrams/litre)
WASTE LOADING (kilograms/hour)
FLOW (litres per second)
RAINFALL (cm/h)
START OF SAMPLING
END OF MANUAL SAMPLING
END OF AUTOMATIC SAMPLING
DETECTION LIMIT OF EQUIPMENT USED FOR DETERMINATION OF CONCENTRATION = 0·02 mg/l
TIME (HOURS)

FIGURE: 116

PARAMETER: Nitrite

LOCATION: BARRINGTON

DATE: SEPT. 11, 1975

TIME OF START OF SAMPLING : 3·45 P.M.

LEGEND:

CONCENTRATION ——— x ——— x ———

WASTE LOADING ——— o ——— o ———

FLOW ———————————

STUDY OF SEPARATED STORM SEWER RUNOFF FROM URBAN AREAS-BOROUGH OF EAST YORK.

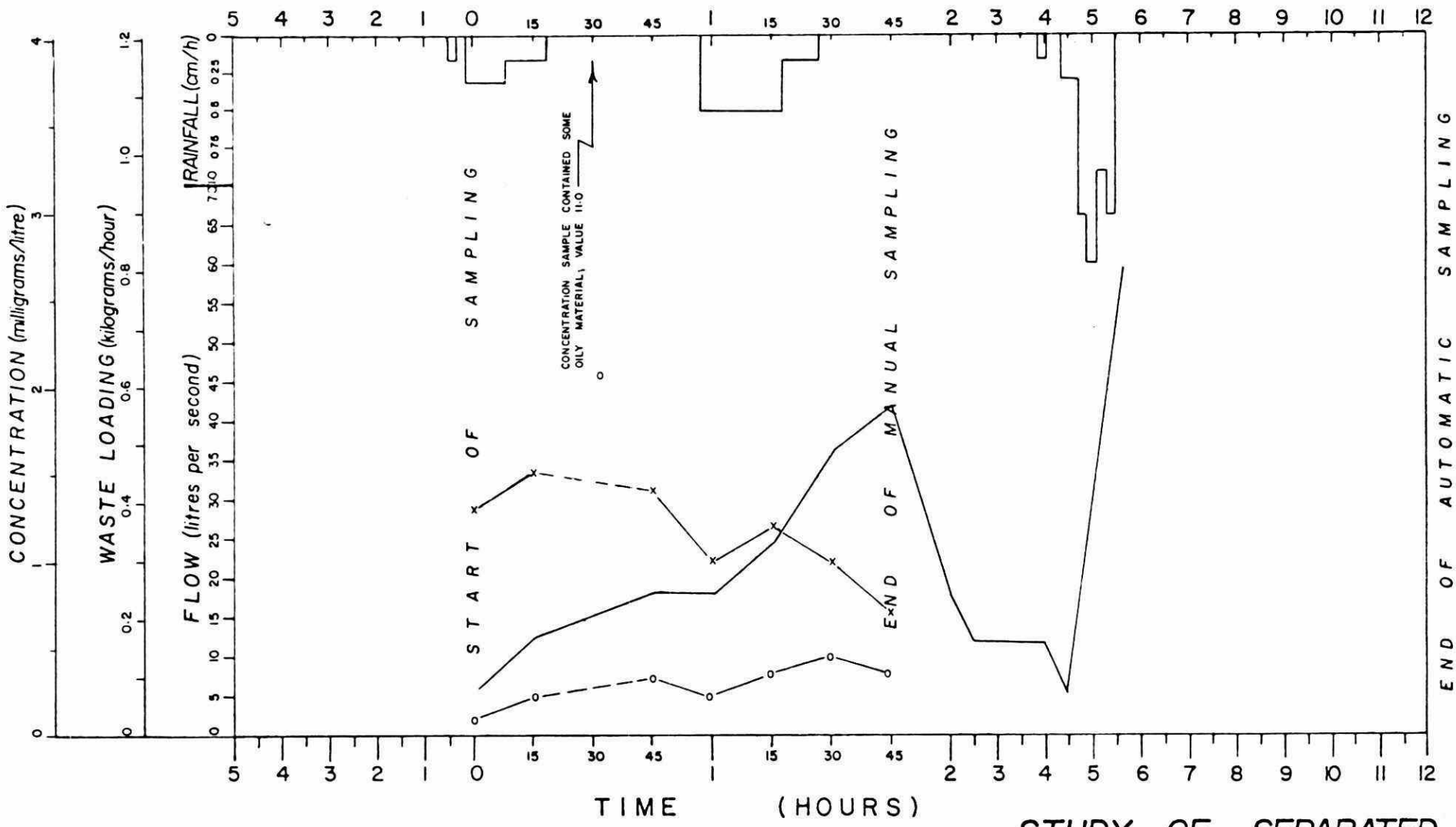

FIGURE: 143

PARAMETER: Phosphorus-Total

LOCATION: BARRINGTON

DATE: SEPT. 11, 1975

TIME OF START OF SAMPLING : 3·45 P.M.

LEGEND:

CONCENTRATION — x — x —

WASTE LOADING — o — o —

FLOW ———

STUDY OF SEPARATED STORM SEWER RUNOFF FROM URBAN AREAS-BOROUGH OF EAST YORK.

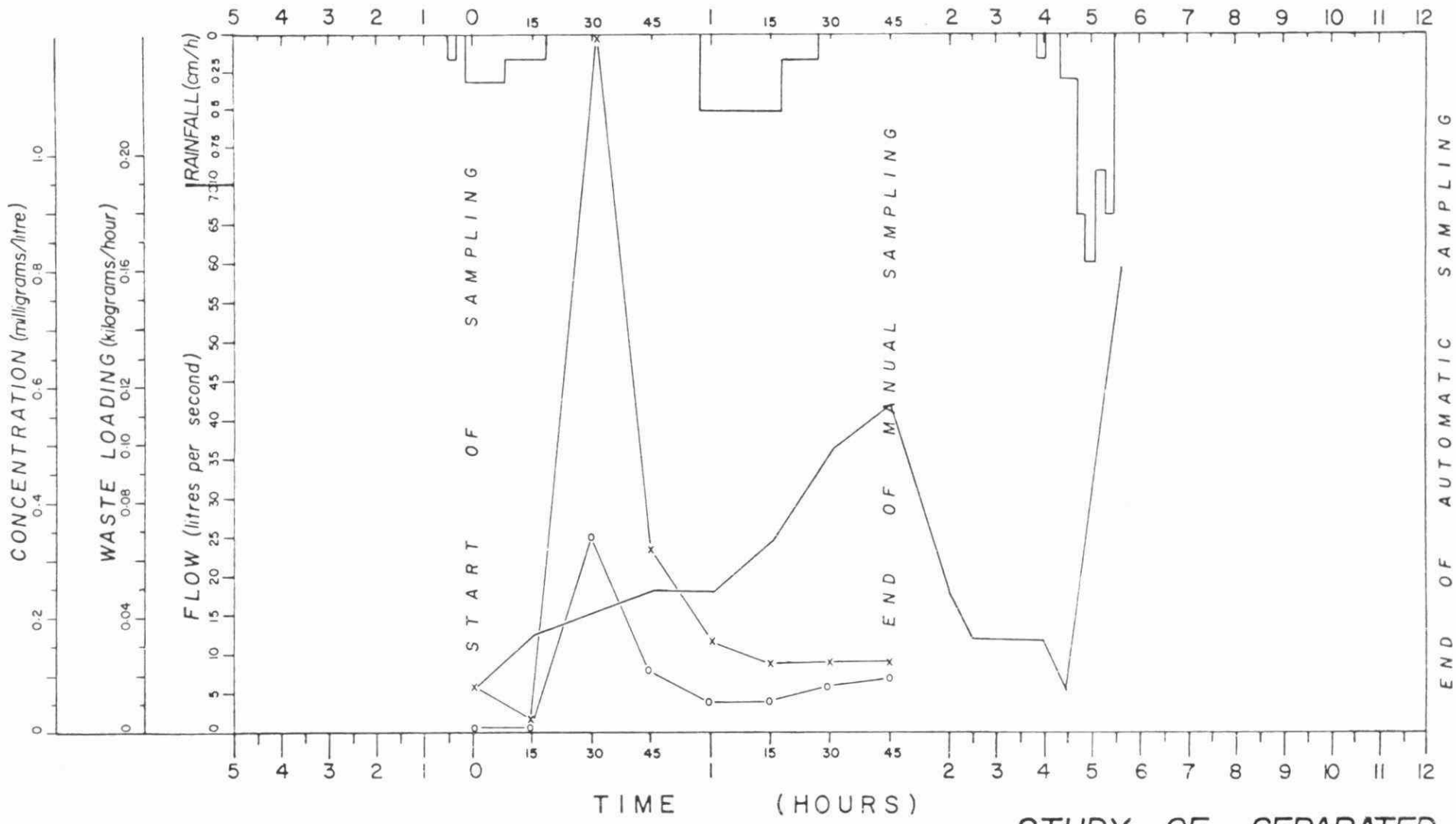

FIGURE: 161

PARAMETER: Phosphorus–Soluble

LOCATION: BARRINGTON

DATE: SEPT. 11, 1975

TIME OF START OF SAMPLING : 3·45 P.M.

LEGEND:

CONCENTRATION —— x —— x ——

WASTE LOADING —— o —— o ——

FLOW ——————

STUDY OF SEPARATED STORM SEWER RUNOFF FROM URBAN AREAS-BOROUGH OF EAST YORK.

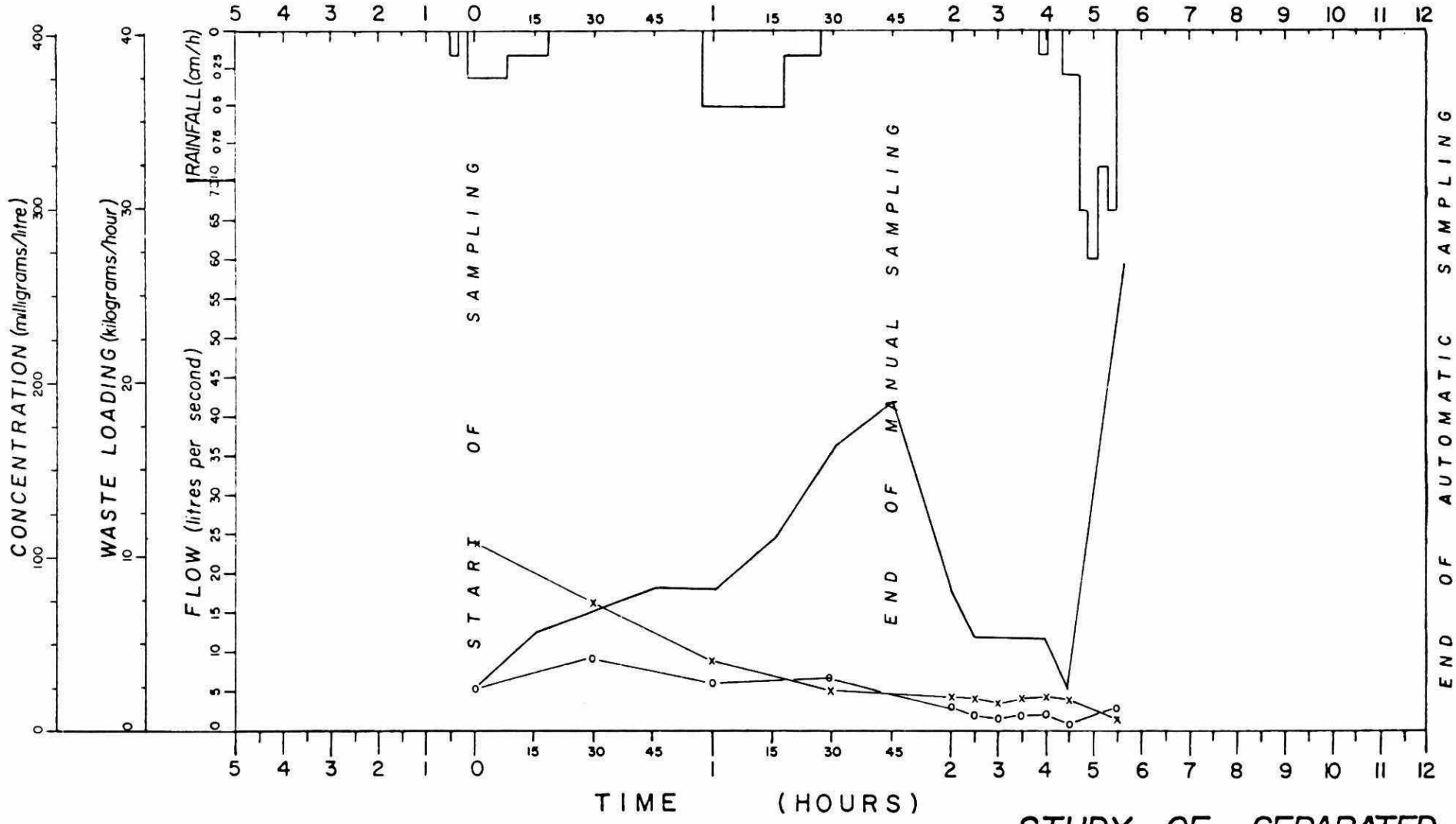

FIGURE: 181

PARAMETER: Chloride

LOCATION: BARRINGTON

DATE: SEPT. 11, 1975

TIME OF START OF SAMPLING : 3·45 P.M.

LEGEND:

CONCENTRATION —— x —— x ——

WASTE LOADING —— o —— o ——

FLOW ————————

STUDY OF SEPARATED STORM SEWER RUNOFF FROM URBAN AREAS - BOROUGH OF EAST YORK.

APPENDIX B

METRO TORONTO BYLAW 2520

THE MUNICIPALITY
OF METROPOLITAN TORONTO

Bylaw No. 2520

To regulate the discharge of sewage and land drainage in the Metropolitan Area.

1. In this bylaw:

(a) "biochemical oxygen demand" or BOD means the quantity of oxygen utilized in the biochemical oxidation of organic matter in 5 days at 20 degrees centigrade expressed in milligrams per litre as determined in accordance with Standard Methods.*

(b) "coliform count" means the number of all coliform bacteria and expressed in number of coliform bacteria per 100 millilitres as determined in accordance with Standard Methods.

(c) "colour of liquid" means the appearance of a liquid from which the suspended solids have been removed, as determined in accordance with Standard Methods.

(d) "Commissioner" means the Commissioner of Works of The Municipality of Metropolitan Toronto or his duly authorized representative.

(e) "grease or fat" means any substance which is extractable from a sample by petroleum ether or other designated solvent, as determined in accordance with Standard Methods.

(f) "Inspector" means a person authorized by the Municipality of Metropolitan Toronto to carry out observations and inspections and to take samples as prescribed by this bylaw.

(g) "mg/l" means milligrams per litre and shall be equivalent to parts per million.

(h) "person" includes a corporation.

(i) "pH" means the logarithm of the reciprocal of the weight of hydrogen ions in grams per litre of solution and shall indicate the intensity of acidity and alkalinity expressed in terms of a pH scale ranging from 0 to 14 with the pH of 7.0 being the mid-point in the scale representing a neutral solution with values above 7.0 indicating the intensity of alkalinity and those below 7.0 the intensity of acidity.

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* Standard Methods for the Examination of Water and Wastewater, 14th edition, prepared and published jointly by APHA, AWWA, and WPCF, 1975.

(j) "phenolic compounds" collectively referred to as phenols mean those hydroxy derivatives of benzene, which can be determined as such by using Standard Methods.

(k) "Standard Methods" means the procedure set out in "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association current at the date of testing.

(l) "suspended solids" means solid matter in or on a liquid that is removable by filtering as determined in accordance with Standard Methods.

(m) "watercourse" means an open channel, ditch or depression either natural or artificial, in which a flow of storm water occurs, either continuously or intermittently.

2. No person shall within the metropolitan area discharge, cause or allow the discharge of storm water into a sanitary sewer except a combined storm and sanitary sewer.

3. Wastewater not prohibited by Section 6 of this Bylaw shall be discharged to a storm sewer or watercourse.

4. No person shall discharge, cause or allow the discharge into the metropolitan sewer system, or any sewer system draining into the metropolitan sewer system of wastewater or matter which may be harmful to the metropolitan sewer system or treatment process or which might tend to obstruct the sewers, or which may be harmful to personnel involved in maintaining or operating the sewage works.

5. No person shall within the metropolitan area discharge into a sanitary sewer or a combined storm and sanitary sewer any of the following:

(a) Wastewater having a temperature more than 150 degrees fahrenheit.

(b) Gasoline, benzene, naphtha, fuel oil, or other inflammable or explosive matter.

(c) Ashes, cinders, sand, mud, straw, shavings, metal, glass, rags, feathers, tar, plastic, wood, cellulose, paunch manure or any other solid or viscous matter that is not dissolved in a liquid, of a type or quantity capable of causing obstruction to the flow in the sewer system.

(d) Carbon bisulphide, hydrogen sulphide, ammonia, trichloroethylene, sulphur dioxide, formaldehyde.

(e) Wastewater having a pH lower than 5.5 or higher than 10.5.

(f) Atomic waste and radioactive materials except as may be permitted under The Atomic Energy Control Act (Canada) and regulations thereunder.

(g) Wastewater containing suspended solids exceeding six hundred (600) mg/l, or having a BOD exceeding five hundred (500) mg/l.

(h) Wastewater containing more than 150 mg/l of fat, oil or grease, or other matter that is soluble in petroleum ether.

(i) Wastewater containing more than 15 mg/l floating oil or grease of a mineral origin or tar, or more than 150 mg/l stable emulsified oil or grease of mineral origin.

(j) Wastewater containing any of the materials set out hereunder in Column I in excess of the concentration respectively set out opposite each material in Column II.

I	II
Phenolic Compounds	1 mg/l
Cyanide	5 mg/l
Sulphides	5 mg/l
Cadmium	8 mg/l
Copper	8 mg/l
Nickel	10 mg/l
Chromium	10 mg/l
Lead	10 mg/l
Zinc	10 mg/l
Chlorides measured as Cl	1500 mg/l
Sulphates measured as SO_4	1500 mg/l

6. No person shall within the metropolitan area discharge, cause or allow the discharge into a storm sewer, storm sewer connection, storm drain, watercourse or land drainage works which is capable of discharging into any body of water or onto the shore or bank thereof any of the following:

(a) Wastewater having a temperature more than 150 degrees F.

(b) Gasoline, benzene, naphtha, fuel oil, or other inflammable or explosive matter.

(c) Ashes, cinders, garbage, sand, mud, straw, shavings, metal, glass, rags, feathers, tar, plastic, wood, cellulose, paunch manure or any other solid or viscous matter.

(d) Carbon bisulphide, hydrogen sulphide, ammonia, trichloroethylene, sulphur dioxide, formaldehyde, chlorine, bromine, pyridine, or any other matter that has or may cause an offensive odour.

(e) Atomic waste and radioactive materials except as may be permitted under The Atomic Energy Control Act (Canada) and regulations thereunder.

(f) Wastewater that is likely to cause the death of or injury to any person, fish, animal, bird or fowl, or that is likely to cause damage to any property.

(g) Wastewater having a pH lower than 5.5 or higher than 9.5.

(h) Wastewater containing suspended solids exceeding 30 mg/l or which are incapable of passing through a quarter-inch screen.

(i) Wastewater which may contain more than 15 mg/l of fat, oil, grease, or other matter that is soluble in petroleum ether.

(j) Wastewater in which the BOD exceeds 20 mg/l.

(k) Coloured wastewater which requires a dilution in excess of 4 parts to 1 part to dissipate the colour till it is not determinable by the colour test.

(l) Wastewater containing any of the materials set out hereunder in Column I in excess of the concentration respectively set out opposite each material in Column II.

I	II
Phenolic compounds	0.04 mg/l
Cyanide	0.10 mg/l
Cadmium	1 mg/l
Chromium	1 mg/l
Nickel	1 mg/l
Copper	5 mg/l
Zinc	5 mg/l
Lead	5 mg/l
Iron	17 mg/l
Chlorides measured as Cl	1500 mg/l
Sulphates measured as SO_4	1500 mg/l

(m) Wastewater in which the coliform count exceeds 2400 per 100 millilitres.

7. Where a wastewater is not amenable to treatment in the Metropolitan Treatment Works, the Commissioner may direct that it be treated to meet the provisions of Section 6 of this bylaw and then discharged to a storm sewer.

8. The discharge of an industrial waste that would otherwise be prohibited by this bylaw may be permitted in the sanitary or combined storm and sanitary system to an extent fixed by agreement with the Metropolitan Corporation under such conditions with respect to payment or otherwise as may be necessary to compensate for any additional costs of treatment.

9. Where in order to prevent the discharge of an effluent to an area or Metropolitan Sewer System exceeding the strength, nature, quantity or quality permitted by this bylaw it is necessary to install a treatment plant, it shall be constructed or installed at a location and according to design and working methods in keeping with good engineering practice and shall be kept in operation for so long as may be necessary to prevent the discharge of such effluent contrary to the provisions of this bylaw.

10. Where grease, oil and grit interceptors are provided at the cost of the owner to prevent the discharge of wastewaters containing amounts of these substances in excess of the amounts permitted by this bylaw they shall be properly maintained and placed in locations readily accessible for cleaning and inspection and shall be of a design in keeping with good engineering practice.

11. Any person discharging wastewater to the sewer system shall ensure that such wastewater conforms at all times to the provisions of this bylaw.

12.(1) The owner of any property served by a sewer, connecting any industrial building, apartment building of more than 30 suites, or shopping centre, with any sewer in the metropolitan area shall install one or more suitable manholes in the said sewer to facilitate observations, sampling and measurement of the wastewater therefrom.

(2) Such manholes shall be of designs in accordance with good engineering practice and shall be constructed and maintained at the cost of the owner on the lands of such owner abutting the property line adjacent to the municipal sewer so that all wastes from the property pass through such manholes.

13. All equipment designed for the treatment or interception of wastewater or matter including inspection manholes shall be subject to inspection at all reasonable times and the Commissioner

or his duly authorized representative, bearing proper credentials and identification, shall be permitted to inspect, observe, measure, sample and test all effluent and drainage.

14. All measurements, tests and analyses of the characteristics of wastewaters to which reference is made in this bylaw shall be determined in accordance with Standard Methods.

15. Every person who contravenes any provision of this bylaw shall upon conviction thereof, forfeit and pay, at the discretion of the convicting magistrate, a penalty (exclusive of costs) not exceeding Three Hundred Dollars ($300.00) for each offence. Each day in which any such contravention continues shall be deemed a separate offence. Such penalties shall be recoverable under the provisions of The Summary Convictions Act.

ENACTED AND PASSED this 2nd day of November, A.D. 1965.

WILBERT W. GARDHOUSE,
Metropolitan Clerk.

WILLIAM R. ALLEN,
Chairman.

(Corporate Seal)

CANADA-ONTARIO AGREEMENT

RESEARCH REPORTS

These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. They provide a central source of information on the studies carried out in this program through in-house projects by both Fisheries and Environment Canada, and the Ontario Ministry of the Environment, and contracts with municipalities, research institutions and industrial organizations.

Inquiries pertaining to the Canada-Ontario Agreement RESEARCH PROGRAM should be directed to -

Wastewater Technology Centre
Canada Centre for Inland Waters
Fisheries and Environment Canada
P.O. Box 5050
Burlington, Ontario L7R 4A6

Ontario Ministry of Environment
Pollution Control Branch
135 St. Clair Avenue West
Toronto, Ontario M4V 1P5

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Water quality of urban storm water runoff in the borough of East York / Mills, W. Gordon.
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